RESEARCH ARTICLE

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Journal of Ecophysiology and Occupational Health, *Vol 25(3), DOI: 10.18311/jeoh/2025/46284, 391-398, September 2025*

ISSN (Online) : 0972-4397
ISSN (Online) : 0974-0805

Preliminary Findings on the Impact of Inspiratory Muscle Training on Blood Pressure, Lung Function, and Functional Capacity in Essential Hypertension: A Pilot Study

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Abstract

This pilot study assessed the feasibility and initial effects of Inspiratory Muscle Training (IMT) on blood pressure, lung function, and functional capacity in individuals with essential hypertension. Thirty adults aged 40–60 years with diagnosed hypertension were recruited from a diagnostic centre near Mallathahalli, Bengaluru, and randomly assigned to an experimental group (n=15) or a control group (n=15). The experimental group participated in a 6-week IMT program using the Threshold Inspiratory Muscle Training device (Respironics) alongside seated diaphragmatic breathing exercises. The control group practiced only slow-paced diaphragmatic breathing exercises. Sessions were conducted six days per week, lasting 30 minutes each, and tailored to individual fitness levels. After six weeks, both groups exhibited reductions in systolic (SBP) and Diastolic Blood Pressure (DBP). The experimental group demonstrated significantly greater reductions, with a mean SBP decrease of 7.93 mmHg (p=0.0001) and DBP decrease of 4.27 mmHg (p=0.0001). Improvements in pulmonary function parameters, including Forced Vital Capacity (FVC), forced expiratory volume in 1 second (FEV1), the FEV1/FVC ratio, and Peak Expiratory Flow Rate (PEFR), were significantly greater in the experimental group compared to controls. Functional capacity, measured via the 6-minute walk test, also improved more substantially in the experimental group. Assessments were conducted at consistent times pre- and post-intervention to minimize variability. Data were analysed using descriptive statistics and paired t-tests. This study highlights the potential of IMT, combined with diaphragmatic breathing exercises, to reduce blood pressure and improve pulmonary and functional health in hypertensive individuals. IMT may effectively decrease sympathetic activity and enhance respiratory and cardiovascular function. Further studies with larger populations are warranted to confirm these findings.

Major Findings: The study revealed that both groups showed significant improvements across various clinical parameters, including SBP, DBP, 6MWD, FVC, and FEV1. However, Group A demonstrated a more pronounced improvement compared to Group B in most outcomes, particularly in blood pressure reduction, exercise capacity, and lung function. These findings suggest that Group A's intervention was more effective in enhancing overall health metrics.

Keywords: Essential Hypertension, FEV1 (Forced Expiratory Volume in 1 Second), FVC (Forced Vital Capacity) Pulmonary Function Tests, Six-Minute Walk Test

Abbreviations: SBP – Systolic Blood Pressure, DBP – Diastolic Blood Pressure, IMT – Inspiratory Muscle Training

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Article Received on: 08.10.2024 Revised on: 11.12.2024 Accepted on: 13.12.2024

1. Introduction

Elevated Blood Pressure (BP), once primarily a public health issue in high-income countries, is now most common in low- and middle-income nations[1]. In India alone, 199 million adults have elevated BP[2], and hypertension is a major contributor to the increasing mortality and disability linked to cardiovascular diseases[3-5]. This rising burden has attracted significant research interest, leading to numerous single-center studies and a few multicenter studies over the past six decades[6].

Hypertension was characterized as self-reported elevated Blood Pressure (BP), specifically defined as a systolic BP greater than 140 mm Hg or a diastolic BP exceeding 90 mm Hg. The estimated prevalence of hypertension among the Indian population aged 45 years and older is 45.9% (95% CI 45.4%–46.5%). Of those with hypertension, 55.7% (95% CI 54.9%–56.5%) had received a diagnosis, 38.9% (95% CI 38.1%–39.6%) were taking antihypertensive medication, and 31.7% (95% CI 31.0%–32.4%) had achieved blood pressure control[7].

Several studies have indicated that an imbalanced autonomic nervous system is a significant factor in the development of hypertension. This imbalance is marked by increased sympathetic activity, often coupled with decreased parasympathetic activity, and it affects not only individuals with early or borderline hypertension but also those with persistent hypertension. Additionally, various cardiovascular risk factors associated with hypertension have been causally linked to heightened sympathetic activity. A possible explanation for this autonomic imbalance may lie in the diminished sensitivity of the baroreflex, which is reset to higher blood pressure levels in hypertensive individuals, thereby impairing its ability to regulate increased sympathetic activity effectively[8-19].

Research has shown that diminished sensitivity of the baroreflex—a regulatory mechanism responsible for controlling blood pressure—is associated with greater blood pressure variability and damage to target organs. Additionally, essential hypertension may involve the activation of chemoreflexes, which can further elevate sympathetic activity and disrupt autonomic balance. To counteract these issues, engaging in diaphragmatic breathing exercises and inspiratory muscle training for 30 minutes, six times a week, has been found to enhance baroreflex sensitivity, decrease sympathetic and chemoreflex activation, and potentially provide beneficial effects on hypertension. These results carry significant implications for clinical management and prognosis[20].

To combat the rising global incidence of hypertension, innovative approaches are essential. Among non-pharmacological interventions, respiratory strength training has shown promising results, including improvements in blood pressure, autonomic balance, and baroreflex sensitivity in individuals with hypertension over time. As hypertension progresses, some individuals may develop resistance to anti-hypertensive medications, requiring optimal doses of three or more drugs, including a diuretic, a condition known as resistant hypertension. To minimize the side effects of multiple medications, non-pharmacological or complementary therapies, such as moderate aerobic exercise, resistance training, isometric exercise, inspiratory muscle training, slow breathing, and relaxation techniques, have shown promising potential in reducing blood pressure[21].

The inspiratory muscles, including the diaphragm, are structurally and functionally classified as skeletal muscles and should respond to training similarly to any locomotor muscle when subjected to an appropriate physiological load. Supporting this notion, studies have shown that the diaphragm thickens in response to resistance applied during weight training[22].

The main goals of this study were: (1) to assess the impact of Inspiratory Muscle Training (IMT) on blood pressure, (2) to evaluate how IMT affects lung volumes, and (3) to investigate whether a 6-week IMT program would enhance functional capacity in individuals with essential hypertension.

2. Materials and Methods

2.1 Study Design

Pilot study featuring a pre-post intervention design.

2.2 Participants

A convenience sample of 30 participants, both male and female, aged 40 to 55 years, all diagnosed with essential hypertension and meeting the inclusion and exclusion criteria, was selected for the study. Participants were recruited from a diagnostic center and primary healthcare facilities. They were then randomly assigned to either a control group or an intervention group, with 15 participants in each group.

2.3 Ethical Considerations

The study received approval from the Institutional Ethics Committee (IEC) at Garden City University, Bengaluru. Informed consent was obtained from all participants. All study procedures were reviewed and authorized by the institutional ethical committee. The nature, benefits, and risks associated with the study procedures were thoroughly explained to the volunteers, and their written consent was secured prior to their participation. Additionally, the study is registered with the Clinical Trials Registry-India (CTRI) under the registration number CTRI/2024/04/066216.

2.4 Allocation Method

Randomization was achieved using a computer-generated randomization sequence to assign participants to either **Group A (which received Inspiratory Muscle Training [IMT]** and diaphragmatic breathing) or **Group B (which performed only diaphragmatic breathing).** The randomization process was stratified based on key variables such as age, gender, and baseline blood pressure to ensure these factors were balanced between the two groups.

2.5 Intervention

The study included 30 participants with essential hypertension, aged 40 to 55 years, both male and female, who met the specified inclusion and exclusion criteria. Standardized pulmonary function tests were conducted, ensuring that participants had FEV1 values of at least 80% and FEV1/FVC ratios greater than 0.7, following established protocol guidelines. All participants provided written consent before the initiation of the training program.

Participants were enrolled in a 6-week inspiratory muscle training program consisting of supervised sessions six times a week. Each session included 30 breaths divided into 5 sets with a 1-minute rest between sets, lasting a total of 30 minutes for the intervention group (Group A, n=15). In contrast, the control group (Group B, n=15) engaged only in diaphragmatic breathing exercises.

Blood pressure measurements (systolic and diastolic) were taken on day 1 and again at the 6th week following the intervention using a sphygmomanometer. Pulmonary function tests, including Forced Vital Capacity (FVC), FEV1/FVC ratio, and Peak Expiratory Flow Rate (PEFR), were assessed using RMS Helios spirometry on both day 1 and at the 6th week after the intervention. Additionally, functional capacity was evaluated using a standardized 6-minute walk test on day 1 and again at the 6th week post-intervention.

3. Results and Discussion

Data analysis was performed using SPSS version 23. The normality of the pretest and post test scores for various parameters in Groups A and B was assessed using the Shapiro-Wilk test. To compare the pretest and post test scores of Systolic Blood Pressure (SBP), Diastolic Blood Pressure (DBP), the 6-minute walk test, and Forced Vital Capacity (FVC) between Groups A and B, the Mann-Whitney U test was employed. The Wilcoxon matched pairs test was used to compare the pretest and post test scores of SBP, DBP, the 6-minute walk test, and FVC within both groups. For the evaluation of pretest and post test scores of FEV1, FVC, FEV1/FVC, and Peak Expiratory Flow Rate (PEFR) between Groups A and B, a paired t-test was utilized. The statistical significance level was established at 5%, with a p-value of less than 0.05 indicating significance (Table 1).

It is important to note that the pretest and post test scores for parameters such as FEV1, FEV1/FVC, and PEFR exhibited a normal distribution; thus, parametric tests were used for analysis. In contrast, the pretest and post test scores for parameters such as SBP, DBP, 6MWD, and FVC did not follow a normal distribution, necessitating the use of non-parametric tests for their evaluation (Figures 1, 2, 3, 4).

The study evaluated the effectiveness of interventions on various health parameters between Group A and Group B, analyzing results according to gender, age, BMI, and several clinical measures. Notable findings were observed in both groups, particularly concerning blood pressure (systolic and diastolic), the 6-Minute Walk Distance (6MWD), Forced Vital Capacity (FVC), Forced Expiratory Volume in 1 second (FEV1), and Peak Expiratory Flow Rate (PEFR). Below is a comprehensive discussion of these findings:

Systolic Blood Pressure (SBP): Both groups exhibited a significant reduction in SBP following the intervention. Group A showed a mean decrease of 7.93 mmHg (p=0.0001), while Group B had a mean reduction of 3.67 mmHg (p=0.0001). The difference in SBP reduction

Table 1. Presents the results of the normality assessment for the pretest and post test scores of various parameters in Groups A and B, as determined by the Shapiro-Wilk test

Parameters	Times	Groups	Shapiro-Wilk	df	p-value
SBP	Pretest	Group A	0.6910	15	0.0001*
		Group B	0.6150	15	0.0001*
	Post test	Group A	0.8080	15	0.0050*
		Group B	0.7170	15	0.0001*
	Difference	Group A	0.9110	15	0.1400
		Group B	0.9340	15	0.3180
DBP	Pretest	Group A	0.7310	15	0.0010*
		Group B	0.8380	15	0.0120*
	Post test	Group A	0.8420	15	0.0140*
		Group B	0.8940	15	0.0770
	Difference	Group A	0.8490	15	0.0170*
		Group B	0.9400	15	0.3810
6MWD	Pretest	Group A	0.9490	15	0.5040
		Group B	0.9560	15	0.6220
	Post test	Group A	0.9390	15	0.3640
		Group B	0.9550	15	0.6140
	Difference	Group A	0.5900	15	0.0001*
		Group B	0.8750	15	0.0400*
FVC	Pretest	Group A	0.8320	15	0.0100*
		Group B	0.8660	15	0.0290*
	Post test	Group A	0.9050	15	0.1130
		Group B	0.8280	15	0.0090*
	Difference	Group A	0.9210	15	0.1990
		Group B	0.9140	15	0.1580
FEV1	Pretest	Group A	0.8940	15	0.0760
		Group B	0.9700	15	0.8510
	Post test	Group A	0.9600	15	0.6990
		Group B	0.9480	15	0.4930
	Difference	Group A	0.9110	15	0.1420
		Group B	0.9680	15	0.8320
FEV1/FVC	Pretest	Group A	0.8880	15	0.0620
		Group B	0.9170	15	0.1750
	Post test	Group A	0.9220	15	0.2090
		Group B	0.9370	15	0.3510
	Difference	Group A	0.8560	15	0.0510
		Group B	0.9800	15	0.9680
FEV1/FVC	Pretest	Group A	0.8880	15	0.0620
		Group B	0.9170	15	0.1750
	Post test	Group A	0.9220	15	0.2090
		Group B	0.9370	15	0.3510
	Difference	Group A	0.8560	15	0.0510
		Group B	0.9800	15	0.9680
PEFR	Pretest	Group A	0.9060	15	0.1160
		Group B	0.8840	15	0.0540
	Post test	Group A	0.8980	15	0.0880
		Group B	0.9590	15	0.6760
	Difference	Group A	0.9520	15	0.5550
		Group B	0.8910	15	0.0550

*p<0.05

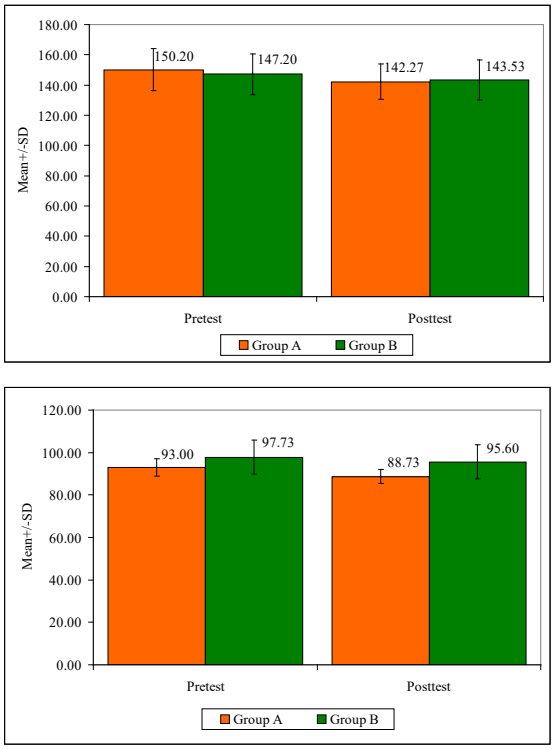


Figure 1. Comparison of pretest and post test scores for SBP and DBP between Group A and Group B.

between the groups was significant (p=0.0032), indicating that the intervention in Group A was more effective in lowering SBP.

Diastolic Blood Pressure (DBP): Group A demonstrated a greater reduction in DBP, with a mean decrease of 4.27 mmHg (p=0.0001), compared to Group B's decrease of 2.13 mmHg (p=0.0001). The post test comparison between the groups was significant (p=0.0107), suggesting that Group A's intervention was more effective in reducing DBP.

Six-Minute Walk Distance (6MWD): The 6MWD improved significantly in both groups post-intervention,

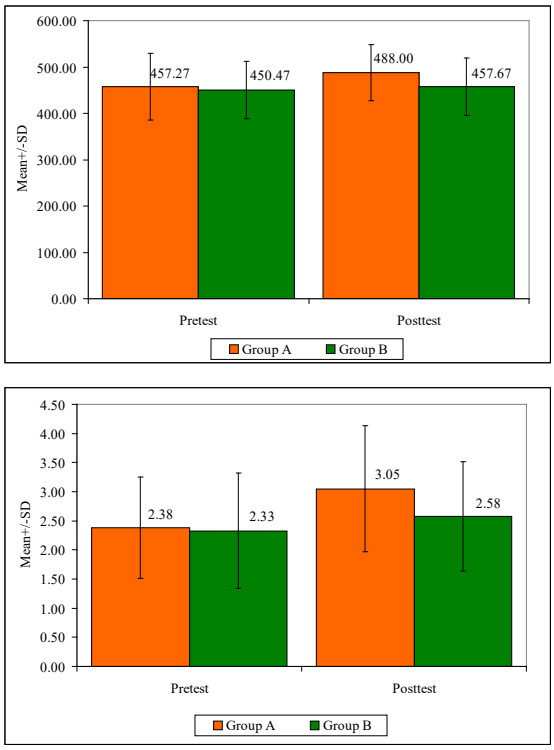


Figure 2. Comparison of pretest and post test scores for 6MWD and FVC between Group A and Group B.

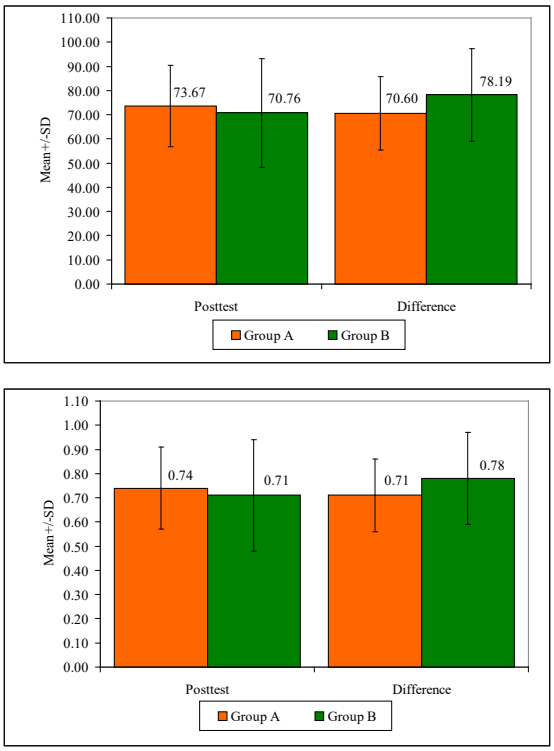


Figure 3. Comparison of pretest and post test scores for FEV1 and FEV1/FVC between Group A and Group B.

but the enhancement was more pronounced in Group A. Group A's pretest value of 457.27 meters increased to 488.00 meters (p=0.0001), while Group B's improvement was more modest, rising from 450.47 meters to 457.67 meters (p=0.0001). The intergroup comparison revealed a significant difference (p=0.0001), indicating that Group A exhibited better functional capacity improvement as measured by 6MWD.

Forced Vital Capacity (FVC): Group A also showed a greater improvement in FVC after the intervention compared to Group B. Group A had a significant increase of 0.67 L (p=0.0001), whereas Group B experienced a smaller gain of 0.24 L (p=0.0001). The difference between the groups was significant (p=0.0003), suggesting that Group A's intervention was more effective in enhancing lung function as reflected by FVC.

Forced Expiratory Volume in 1 Second (FEV1): Both groups showed significant improvements in FEV1, with Group A experiencing a more substantial increase of 0.70 L (p=0.0001) compared to Group B's increase of 0.12 L (p=0.0211). The intergroup difference was significant (p=0.0001), indicating superior outcomes for Group A in terms of FEV1 improvement.

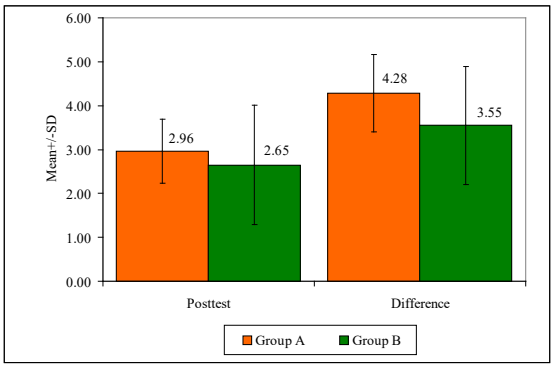


Figure 4. Comparison of pretest and post test scores for PEFR between Group A and Group B.

FEV1/FVC Ratio: The FEV1/FVC ratio improved significantly in Group A, with an increase of 7.43% (p=0.0039), while Group B did not show any significant change. The difference in the changes of the FEV1/FVC ratio between groups was significant (p=0.0006), highlighting the effectiveness of Group A's intervention in enhancing pulmonary function.

Peak Expiratory Flow Rate (PEFR): Both groups demonstrated improvements in PEFR post-intervention, but Group B had a larger increase (1.32 L/min, p=0.0001)

compared to Group A (0.90 L/min, p=0.0001). Although Group B showed a greater percentage change, the difference between the groups approached significance (p=0.0500), indicating that the interventions were comparably effective in enhancing PEFR.

The significant differences observed in the reductions of SBP and DBP between the groups (p=0.0032) suggest a more substantial improvement in Group A. The intergroup comparison of changes in 6MWD also showed significant improvement in Group A (p=0.0001). Furthermore, both groups exhibited notable improvements in PEFR, with Group A increasing by 0.90 L/min (p=0.0001) and Group B by 1.32 L/min (p=0.0001), while the difference between groups was marginally significant (p=0.0500). Overall, the findings demonstrate that Group A had more pronounced improvements across various health parameters, particularly in blood pressure and lung function.

4. Conclusion

This pilot study investigated the feasibility of various techniques for reducing essential hypertension. Although there are limited studies on the effectiveness of inspiratory muscle training compared to conventional aerobic training, our findings indicate that it can significantly lower both systolic and diastolic blood pressure by 9 mmHg and 5 mmHg, respectively, through a reduction in sympathetic activity and enhancement of baroreflex activity within the autonomic nervous system.

The analysis revealed substantial improvements in several health parameters across both groups, with Group A demonstrating greater enhancements in systolic blood pressure (SBP), diastolic blood pressure (DBP), 6-Minute Walk Distance (6MWD), Forced Vital Capacity (FVC), FEV1, and the FEV1/FVC ratio compared to Group B.

5. Significance/Implications for Future Research

The findings of this study underscore the importance of translating research results into clinical practice by incorporating inspiratory muscle training as part of a comprehensive management strategy for essential hypertension. Healthcare providers should be educated about the potential benefits of this intervention and its role in enhancing overall cardiovascular health. Future studies should encourage self-management strategies and explore the effects of adjunctive therapies to alleviate the financial burden and disability faced by hypertensive patients.

6. Acknowledgments

We would like to express our sincere gratitude to all the participants in this pilot study for their time and dedication. We extend special thanks to the healthcare professionals and research assistants who aided in the data collection process, as well as to our collaborators for their valuable insights and expertise. We are also appreciative of the institutional support provided by Prudence Diagnostics, whose resources and guidance were essential for the successful completion of this study. Finally, we would like to thank our colleagues, friends, and family members for their encouragement and motivation throughout this journey.

7. Funding and Conflicts of Interest

The authors declare that there are no conflicts of interest associated with this pilot study. There was no external funding or financial support, nor any involvement from third parties that influenced the design, methodology, or outcomes of the research. All findings presented result from the authors' independent analysis and interpretation. The study results are reported transparently and truthfully, with no instances of fabrication, falsification, or inappropriate data manipulation.

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