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# RESPIRATORY MUSCLE TRAINING ON DIAPHRAGM THICKNESS, PULMONARY FUNCTION TEST AND RESPIRATORY MUSCLE STRENGTH IN HEALTHY YOUNG ADULTS: A RANDOMIZED CONTROLLED TRIAL

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**Abstract**

Background: Respiratory muscle training (RMT) has been proposed as an effective means to increase the strength of the inspiratory and expiratory muscle. The RMT offers resistance to inhalation and exhalation and causes an increased strain on the respiratory muscles.

Purpose: The aim of this study was to examine whether simultaneous RMT training (Both on inspiration & expiration) resulted in changes in diaphragm thickness, respiratory muscle strength and pulmonary function in healthy young adults.

Methods: In this study we evaluated the effect of 8 week (10 sessions per week) simultaneous RMT training program in 60 healthy young adults. The participants were stratified for age and aerobic capacity; and randomly assigned either to the experimental group (n=30) or to the control training group (n=30). The program consisted of 8 weeks during which the experimental group performed RMT training (Power lung) program of differing intensities and the control group performed simultaneous RMT training at baseline. Pressure threshold respiratory muscle training was undertaken at the 30-repetition maximum load (50% of the peak inspiratory and expiratory mouth pressure, MIP or MEP, respectively). Each subject underwent testing of pulmonary function test, maximum inspiratory and expiratory pressures (MIP and MEP) and diaphragmatic thickness (tdi) was measured via two-dimensional B-mode ultrasound.

Results: The respiratory muscle training group demonstrated significant increase in FVC, $FEV_1$, $FEV_1$/FVC, Tdi, MIP, MEP compared with the control group. The mean diaphragm thickness in the training group was 0.31 (0.19) while that of the control group was 00.00 (0.16). An increase was observed in the training group at 50 % of their MIP- 102.37 cm $H_2O$ (9.93) to a mean of 109.23 (9.44) cm $H_2O$ & MEP from a mean of 108.53 cm $H_2O$ (10.50) to a mean of 109.23 (9.44) cm $H_2O$.

Conclusion: The finding of this study suggest that respiratory muscle training resulted in an increase of diaphragm thickness, MIP, MEP, FVC, $FEV_1$, $FEV_1$/FVC in healthy young adults.

## Introduction

Respiratory muscles are skeletal muscles that are morphologically and functionally similar to locomotor muscles. Their primary task is to displace the chest wall and therefore move gas in and out of the lung.[1,2] The diaphragm is the primary muscle of ventilation, accounting for approximately 70% to 80% of the inspiration during quiet breathing.[3,4] The diaphragm is active throughout the life of an individual and represents the sole skeletal muscle that is essential for life. The function of the diaphragm is modified by factors such as neural recruitment strategies and mechanical linkages between the different segments of the diaphragm.[5] By analogy with other striated muscles, alterations in the mass of diaphragm muscle tissue have a major influence on diaphragmatic strength and endurance.[6]

There are many approaches to train the respiratory muscles. Three technique commonly used to improve the inspiratory muscle strength are voluntary isocapnic hyperapnea, flow resistive loading and pressure threshold loading. [7] For expiratory muscle strength the diaphragmatic strengthening exercise (using weights) is employed. This increases the strength and endurance of the diaphragm.[2]

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Respiratory muscle training offers resistance to inhalation and exhalation and causes an increased strain on the respiratory muscles.[8,9] Exercise performance in people with chronic obstructive pulmonary disease (COPD) and also healthy adults has been shown to improve with the use of the respiratory muscle training[7,10] This technique has been shown to facilitate pulmonary function. It also improves the ventilation in patients with pulmonary dysfunction associated with weakness and atrophy. It further improves the cough mechanism in patients suffering from a weakness of the abdominal muscles.[4] Respiratory muscle training is performed using progressive threshold resistance. The goal of this type of training is to implement training specific to a group of muscles in order to improve the ability of the muscles to meet the demands placed upon them with less stress & effort.[6]

Previous studies have demonstrated that inspiratory muscle training (IMT) resulted in increased contracted diaphragm thickness and increased lung volumes and exercise capacity in people who are healthy, although the effect of both inspiratory and expiratory muscle training in healthy young adult is yet to be determined. Respiratory muscle training (RMT) has been proposed as an effective means to increase the strength of the inspiratory and expiratory muscle. However, there is still a need to study the effect of respiratory muscle training on diaphragm thickness. The measurement of diaphragm thickness is performed using B-mode ultrasound at the zone of apposition.[2,11,12] The diaphragm thickness in the zone of apposition is proportional to inspired volume and inspiratory force[12,13] and during abdominal breathing there is greater thickening and shortening of diaphragm. [5,12] Therefore, the aim of this study was to examine whether simultaneous RMT training resulted in changes in diaphragm thickness, respiratory muscle strength and pulmonary function in healthy young adults.

**Method**

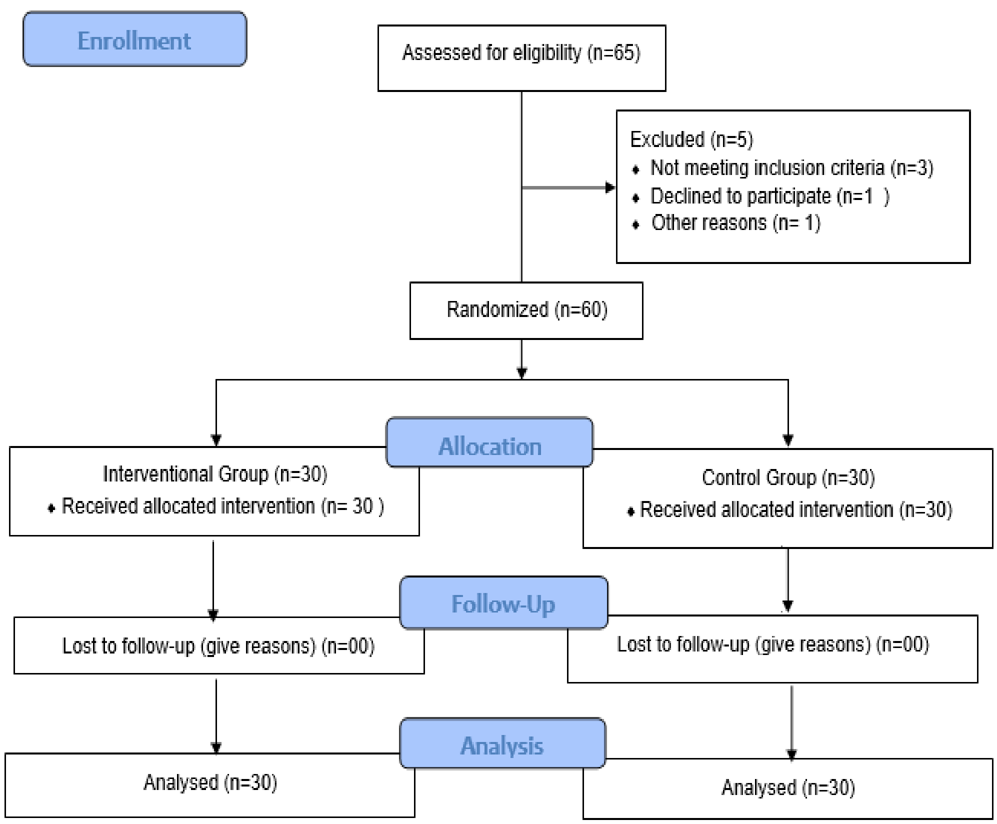


**Figure 1: CONSORT 2010 Flow Diagram**

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**Subjects**

60 young adults of both sexes (19 male, 41 female) who were healthy and who were students attending the University of Manipal (India), take part in this investigation. Approval from the Department of Physiotherapy, the Scientific Committee and the Institutional Ethics Committee of KMC Mangalore was obtained, following which permission was taken from the Dean, KMC, Mangalore, Manipal University for the recruitment of students for the study. All subjects were nonsmokers and had no evidence of pulmonary pathology (eg, asthma) or any known metabolic or endocrine disorder. Subjects were informed of the nature of the study and gave full verbal assent and written consent prior to the study.

All the subjects were then randomly selected and randomized through block randomization into 2 Groups (30 in each): Respiratory muscle training group (Power lung training) and Control group (Respiratory muscle training without any load). Baseline measures like Maximal Inspiratory Pressure (MIP), Maximal Expiratory Pressure (MEP), Pulmonary Function Test (FVC, $FEV_1$, $FEV_1$/FVC), weight, height was taken.

**Study Design**

Randomized Controlled trail

**Measurement protocols**

**Pre-training assessments**

In all subjects, stature (in centimeters) and weight (in kilograms) were determined using a stadiometer (accurate to 1.5 mm) and an electronic beam scale (Inscale electroscale, model MRP200P) (accurate to 0.1 kg).

**Lung function measurements**

All subjects performed maximal expiratory flow maneuvers using a Spirobank G USB Spirometer (USA) in order to determine the forced expiratory volume in 1 second ($FEV_1$), forced vital capacity (FVC), and $FEV_1$/FVC ratio, PEF. During all measurements, subjects were seated and a single experienced technician obtained recordings. All lung function measurements were expressed in liters and as a percentage of the predicted values for age, height, and sex.

**Inspiratory muscle function and expiratory muscle function**

The MIP and MEP were assessed as expressions of inspiratory and expiratory muscle strength using a hand-held mouth pressure meter (P Morgan, UK) in the sitting position. The MIP and MEP manoeuvres were initiated at residual volume (RV) and total lung capacity (TLC), respectively. The assessment of maximal pressures required a sharp, forceful effort maintained for a minimum of ~2 s. The pressure meter incorporated a 1 mm leak to prevent glottic closure during the MIP manoeuvre and to reduce buccal muscle contribution during the MEP manoeuvre Participants were given prior instructions and were verbally coached throughout the manoeuvre.

**Assessment of diaphragm thickness**

In all participants diaphragm thickness (in millimeters) was assessed by B-Mode ultrasonography performed by the radiologist. With the subject standing, the eighth and ninth intercostal spaces in the right mid-axillary line were identified and marked with a wax pencil.[13] With the subject then lying horizontally on a plinth in the left lateral decubitus position, using the sector mode, and with the transducer (PLE 705S 7.5-MHz linear probe) held perpendicular to the chest wall, a 2-dimensional coronal image of the diaphragm at the zone of apposition was identified in either the eighth or ninth intercostal space. The diaphragm was identified by 2 clear parallel echodense lines and was measured from the middle of the pleural to the middle of the peritoneal line.

Participants who received sham training (control group) {n=30} breathed through the same respiratory muscle training device with no additional load and similar baseline measurements were recorded. Outcome measures were recorded after 8 weeks.

**METHOD OF PERFORMING RESPIRATORY MUSCLE TRAINING:**

The Participants were positioned sitting in a chair and instructions were given regarding the whole procedure. They were then instructed to perform warm up activities like gentle stretching of the muscles. After this a demonstration was given regarding the use of respiratory muscle Trainer.

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The s Participants held the RMT (Power lung) in the mouth for inspiration, breathing in through the device for 3 seconds till the lungs filled as completely as possible, and for expiration, breathing out through the device for 3 seconds till the lungs were completely empty.[8,14,15] Respiratory muscle training was undertaken at the 30 repetition maximum load (~50% of the peak inspiratory and expiratory mouth pressure, MIP or MEP, respectively) 2 times per day for 8 weeks (10 sessions per week).[15]

Following this training session, diaphragm thickness was measured using B-mode ultrasound [2,11,12] and Maximal Inspiratory Pressure (MIP) and Maximal Expiratory Pressure (MEP) were determined with the P-Morgan device and pulmonary function test (FVC, $FEV_1$, $FEV_1$/FVC and PEF).

The control group (n=30) performed simultaneous RMT training at baseline (without any workload). Outcome measures were recorded after 8 weeks.

**Statistical analyses**

All statistical analysis was performed using the Statistical Package for Social Science (SPSS) version 13.0 software. P-value of $P < 0.05$ with confidence interval of 95% was considered statistically significant. Values are expressed as mean± SD (Standard Deviation).

The Karl Pearson coefficient correlation was done to find out the correlation between $FEV_1$, FVC, $FEV_1$/FVC, PEF and diaphragm thickness, MIP, MEP in both the training and control group. Students paired t-test was used to find pre- and post-training comparison values within the group. A Mann-Whitney test was used to find the difference between the training group and the control group.

**Results**

All Participants had complete data sets of baseline and post-training measurements of diaphragm thickness, pulmonary function test, MEIP, MEP. There were no differences in age, gender, body weight and BMI between the groups at baseline. In addition, there were no differences in the primary outcome measures of diaphragm thickness, pulmonary function test, MEIP, MEP between the groups at baseline.

**Table-1:** Baseline Measures, Pulmonary Function, Diaphragm Thickness, Maximal Inspiratory Pressure and Maximal Expiratory Pressure

| | **Training Group** | **Control Group** | **P (Between Group)** |
|---|---|---|---|
| **Age(years)** | 23.17 (0.791) | 22.93 (0.785) | 0.256 (NS) |
| **Sex(male/female)** | 12/18 | 7/23 | |
| **Weight (lb)** | 133.47 (21.444) | 131.77 (20.970) | 0.625 (NS) |
| **Height (inch)** | 65.17 (3.733) | 64.70 (2.830) | 0.587 (NS) |
| **FVC(l/sec)** | 0.20 (0.28) | 0.04 (0.31) | 0.042 (Sig) |
| **$FEV_1$(l/sec)** | 0.23 (0.24) | 0.10 (0.29) | 0.070 (NS) |
| **$FEV_1$/FVC** | 4.71 (3.53) | 1.41(4.45) | 0.001 (HS) |
| **PEF(l/sec)** | 0.0873 (0.47220) | 0.0597(0.42659) | 0.379 (NS) |
| **Tdi (mm)** | 0.31 (0.19) | 0.00 (0.16) | <0.0001 (HS) |
| **MIP ($cmH_2O$)** | 6.87 (3.42) | 2.63 (3.85) | <0.0001 (HS) |
| **MEP ($cmH_2O$)** | 6.60 (4.10) | 1.57 (5.61) | <0.0001 (HS) |

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* The training group (n=30) completed an 8-week program of respiratory muscle training. Control group (n=30) did not participate in any form of training. FVC-Forced Vital Capacity, $FEV_1$-Forced expiratory volume in 1 sec, Tdi - Diaphragm Thickness, MIP-Maximal inspiratory Pressure, MEP- Maximal Expiratory Pressure.

**EFFECTS OF RMT TRAINING ON DIAPHRAGM THICKNESS, MIP & MEP**

Following 8 weeks of respiratory muscle training the mean diaphragm thickness increased from 1.83 ± 0.27 cm to 2.15±0.28 (P<0.0001) in training group. While that of the control group was not showed any difference. There was a highly significant difference found between the two groups with respect to diaphragm thickness (p=0.0001, HS).

Respiratory muscle training was associated with increases in inspiratory and expiratory muscle strength. Both MIP and MEP increased to a similar degree. MIP increased from a mean of 102.37 ±9.93 cm $H_2O$ to a mean of 109.23±9.44 cm $H_2O$ (<0.0001), and MEP increased from a mean of 108.53 ± 10.50 cm $H_2O$ to a mean of 115.13 ± 10.50 cm $H_2O$ (P<0.0001). There was no significant difference of MIP & MEP in control group. But, thereby resulting in a significant difference between the training group and the control group (*P*<0.0001).

**Table-2:** Group Comparisons before and after training for Diaphragm Thickness (Tdi), Maximal inspiratory Pressure (MIP) and Maximal Expiratory Pressure (MEP).

| | Group | Before Training | After Training | P(Main effect of time) | P(Main effect of group) |
|---|---|---|---|---|---|
| **Tdi(mm)** | Training | 1.83 (0.27) | 2.15 (0.28) | <0.0001(HS) | |
| | Control | 1.78 (0.25) | 1.78 (0.26) | 0.909(NS) | <0.0001(HS) |
| **MIP(cm$H_2O$)** | Training | 102.37 (9.93) | 109.23 (9.44) | <0.0001(HS) | |
| | Control | 101.37 (8.67) | 104.00 (8.04) | 0.001(HS) | <0.0001(HS) |
| **MEP(cm$H_2O$)** | Training | 108.53 (10.50) | 115.13 (10.50) | <0.0001(HS) | |
| | Control | 107.00 (9.79) | 108.57 (9.61) | 0.137(NS) | <0.0001(HS) |

* Tdi- Diaphragm Thickness, MIP- Maximal Inspiratory Pressure, MEP-Maximal Expiratory Pressure

**EFFECTS OF RMT TRAINING ON PULMONARY FUNCTION TEST**

Following 8 weeks of IMT, there were statistically significant changes in FVC, $FEV_1$, $FEV_1$ / FVC in the RMT group but there were no changes in the control group. There was no significant change in the PEF in either the training group or the control group (Table 2).

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**Table-3:** Group comparison before and after training for Pulmonary Function Tests
* The training group (n=30) completed a 8-week program of power lung training. The control group (n=30) did not participate in any form of training. FVC-Forced Vital Capacity, $FEV_1$-Forced expiratory volume in

| | Group | Before Training | After Training | P(Main effect of time) | P(Main effect of group) |
|---|---|---|---|---|---|
| **FVC(l/sec)** | Training | 3.29 (0.68) | 3.49 (0.83) | P<0.0001(HS) | 0.042 (sig) |
| | Control | 3.44 (0.57) | 3.48 (0.57) | 0.469 (NS) | |
| **$FEV_1$(l/sec)** | Training | 3.07 (0.62) | 3.29 (0.69) | P<0.0001(HS) | 0.070 (NS) |
| | Control | 3.23 (0.53) | 3.33 (0.63) | 0.063(NS) | |
| **$FEV_1$/ FVC** | Training | 93.52 (7.02) | 98.23 (5.85) | P<0.0001(HS) | 0.001 (HS) |
| | Control | 97.10 (5.30) | 98.50 (6.26) | 0.094(NS) | |
| **PEF(l/sec)** | Training | 4.87 (0.92) | 4.95 (0.93) | 0.319(NS) | |
| | Control | 4.47 (0.72) | 4.41(0.66) | 0.450(NS) | 0.379(NS) |

1 sec, PEF- Peak Expiratory Flow. The training group had significantly higher values of FVC, $FEV_1$/FVC compared to the control group.

**Discussion**

The present study is aimed at evaluating the effect of respiratory muscle training on diaphragm thickness in healthy young adults.

The respiratory muscle training offers resistance to both inhalation and exhalation thereby causing the strengthening of inspiratory and expiratory muscles.[8,9] In our study, the results showed a significant improvement in the inspiratory and expiratory muscle strength. This was supported by the study performed on respiratory muscle training in athletes.[8,14,15] The effect of respiratory muscle training on diaphragm thickness, expiratory flow and respiratory muscle strength in healthy young adults was evaluated in the present study. Whereas, an earlier study investigated on parameters such as pulmonary function test, exercise capacity and maximal and sub-maximal exercise.[8] In our study respiratory muscle training was found to improve diaphragm thickness, maximal inspiratory pressure, maximal expiratory pressure and pulmonary function parameters like FVC, $FEV_1$ and $FEV_1$ /FVC.

The mean difference of diaphragm thickness pre- to post-training was 0.31mm. This mean difference is considered clinically significant when compared to the previous study using inspiratory muscle training (IMT) which showed a difference of 0.34mm of diaphragm thickness following 8 weeks of training.[2] The same results were observed in a period of 8 weeks in the present study. These changes could be due to the training of both inspiratory and expiratory muscles. IMT involves only inspiratory muscle training. The increase in diaphragm thickness may be due to a greater retention of sarcomeres in the zone of apposition. [12]

MIP and MEP demonstrated a significant increase following training. Mean improvement in MIP and MEP were 6.87 and 6.60 pre- to post-training respectively. Earlier study evaluated the effects of respiratory muscle training in young athletes for a duration of 6 weeks. The results showed a mean improvement of 8.35 and 8.76 in MIP and MEP.[16] In our study improvement in the MIP and MEP could be due to neural adaptation at the level of the motor unit. Neural adaptation in skeletal muscles includes an increase in the number of motor neurons and the recruitment of motor units to muscles.[2,16]

Our study showed a significant increase in FVC, $FEV_1$ and $FEV_1$/FVC between the groups. There was a mean change of 0.20 l/sec (FVC), 0.23 l/sec ($FEV_1$) and 4 l/sec ($FEV_1$/FVC) between the training and control groups. According to an earlier study, a mean change of, 0.36 l/sec, 0.32 l/sec and 4.7 l/sec in FVC, $FEV_1$, $FEV_1$/FVC was considered to be significant after 5 weeks of power lung training in athletes.[15] The improvement in the training group was highly significant when compared to that of the control group. This increase in FVC, $FEV_1$ might be due to the increased strength of the respiratory muscles, an increased use of the diaphragm during expiratory manoeuvre and better coordination of the muscles in expelling air.[20]

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The results were found to contradict earlier studies where there was no change in $FEV_1$, FVC, $FEV_1$/FVC and PEF following 27.5 days, 2 week and 4 weeks of respiratory muscle training.[8, 9, 18]

The finding of this study revealed an increase in diaphragm thickness leading to increased MIP and MEP with respiratory muscle training, which in turn resulted in improved pulmonary mechanics.

**Limitations of the study**:

Confounding factors which could have influenced the diaphragm muscle strength and thickness in the experimental group would have been physical fitness of subjects.

**Implications for Future Research:**

1) Further studies are needed to find out the effectiveness of Respiratory muscle training on diaphragm thickness in COPD, Duchene's muscular dystrophy, and cystic fibrosis patients.

2) Additional studies are needed to establish specific guidelines for frequency, intensity and duration of training which will maximize improvements in both inspiratory and expiratory muscle function and diaphragm thickness following training with the respiratory muscle trainer.

**Conclusion**

The present study concludes that respiratory muscle training resulted in an increase of diaphragm thickness, MIP, MEP, FVC, $FEV_1$, and $FEV_1$/FVC in healthy young adults.

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**Conflict of Interest Statement**: None

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