

Effect of Inspiratory Muscle Training on Pulmonary Function in Multiple Sclerosis Patient

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ABSTRACT

Background: Multiple sclerosis (MS) is a primary, chronic inflammatory, and progressive disease caused by the demyelination of the central nervous system that may affect motor pathway and cause muscle weakness, respiratory muscles also affected, MS is one of the most common diseases of CNS in younger adults with incidence of 30-110 per 100,000 adults worldwide and affecting approximately 2.5 million people worldwide. Weakness of the respiratory muscles can result in impaired coughing efficacy, potentially leading to aspiration pneumonia or abrupt ventilatory failure, conditions that often result in mortality in multiple sclerosis. Training the respiratory muscles may enhance respiratory function and cough effectiveness.

Objectives: To investigate the effects of inspiratory muscle training (IMT) on pulmonary function in MS patients.

Methods: The neurology department of Minia University Hospital selected a sample of 40 MS patients, aged 25-45, from both genders (26 women and 14 men). The patients were randomly assigned to two groups, each of which received 24 sessions, three times per week, for a period of eight weeks. In addition to conventional chest physiotherapy, twenty patients with multiple sclerosis in Group A received inspiratory muscle training using an IMT device. Twenty patients in Group B received conventional chest physiotherapy exclusively. Before and after treatment, both groups underwent assessments of their pulmonary functions (P_{lmax}, FVC, FEV₁, MVV, PEFs). Results: The pulmonary functions (FVC, FEV₁, P_{lmax}, MVV, PEF) in group (A) increased by 22.74%, 27.72%, 39.20%, 33.34%, and 35%, respectively, following the treatment regimen. In group (B), the P_{lmax} increased by 17.52%.

Conclusion: The primary choice in the rehabilitation program of multiple sclerosis patients should be Inspiratory Muscle Training (IMT), as it has been shown to significantly enhance pulmonary functions by increasing the strength of the respiratory muscle.

Keywords: Multiple sclerosis, pulmonary functions, Inspiratory muscle training.

1. INTRODUCTION

Multiple Sclerosis (MS) is a long-lasting inflammatory condition of the nervous system that affects approximately 2.5 million individuals globally¹. Despite MS being a condition with an unknown cause, it is widely acknowledged that it results from an atypical immune reaction within the central nervous system that can disrupt motor pathways and cause damage, resulting in muscle weakness, which may also affect the respiratory muscles.² Even in individuals with the initial phases of the illness, inadequate ventilation and coughing arise from weak respiratory muscles, potentially resulting in aspiration, pneumonia, or even acute respiratory failure.³ Moreover, pulmonary complications such as aspiration pneumonia, atelectasis, or acute respiratory failure significantly impact the reduced quality of life and mortality.^{4,5}

In MS, the three most common respiratory issues are difficulty in breathing control, impairment of bulbar function, and paralysis of respiratory muscles.⁵ Respiration is affected in individuals with Multiple Sclerosis (MS) due to the potential compromise of the Upper Motor Neurons (UMNs), which regulate the muscles responsible for inspiration and expiration. For example, the diaphragm's strength is reduced as a consequence of injury to the UMNs that supply the phrenic nerve. Furthermore, the external, internal, and innermost intercostals experience a decline in function as a result of injury to UMNs that stimulate intercostal nerves. Respiratory infections, which are caused by aspirations and the inability to clear lung secretions, are a significant cause of mortality in individuals with MS.⁶ Neuromuscular disorders frequently result in inspiratory muscle paralysis. It is occasionally associated with a persistent increase in arterial carbon dioxide levels. Excluding trauma, MS is the predominant cause of long-lasting disability among young individuals across central nervous system problems⁷.

Inactivity can lead to postural hypotension, constipation, urinary retention, osteoporosis, melancholy, and deconditioning, as well as a reduction in lung capacity. The capacity of individuals with Multiple Sclerosis (MS) to engage in activities of daily living (ADL) is limited by their low exercise tolerance, which results in fatigue and shortness of breath during physical activity.⁸ The impact of training respiratory muscle strength and endurance through the use of a variety of resistive breathing devices has been the subject of investigation. The selection of an inspiratory muscle trainer (IMT) is justified by the fact that a weakened inspiration increases the susceptibility of the respiratory muscles to exhaustion and exacerbates the sensation of dyspnea.⁹

Over the last 10 years, there has been growing interest in respiratory training in MS patients. In recent therapies treatments focused on preventing rise of work of breathing factors, thus postponing fatigue. These patients were mainly instructed costal and diaphragmatic breathing in order to reduce accessory muscles contraction. One of the few current studies of this sort concentrate on inspiratory muscle training (IMT) and expiratory muscle training (EMT) which have shown superior results as compared with the above treatments.¹⁰ Respiratory muscle training was developed to treat chronic obstructive pulmonary disease (COPD) and asthma et al. The literature on respiratory conditioning in patients with MS is sparse. Also, this was one the of few studies with small sample size and short intervention period, performed on non-MS subjects with high load which is hard to recruit for MS patients because of fatigue and muscles. However, the scant literature points to positive effect of progressive load training on inspiratory/expiratory strength with 8–12 weeks of training^{11,12} Gender differences were found in relation to depression and stress; females reported higher levels of depression and stress compared to males. Similarly, females were experiencing more severe stress and anxiety symptoms¹³. Still, more research is needed to define and recommend treatment guidelines for MS patients in respiratory rehabilitation.

When difficulty breathing even in patients with normal respiratory function tests due to decreased respiratory muscle force. It has been shown that patients with inspiratory muscle weakness have more dyspnea and lower functional exercise capacity. Respiratory functional tests should be monitored to detect worsening in MS patients in MS, we propose that since pulmonary complications are major contributors for morbidity and mortality, individualized treatment based on the assessment of respiratory muscles and pulmonary function significantly can improve quality of life as well survival.¹⁴ Guidelines encourage active treatments that address psychoso cial factors and focus on functional improvement¹⁵.

The present study aims to examine Effect of Inspiratory Muscle Training on Pulmonary Function in Multiple Sclerosis Patient. We hypothesized that inspiratory muscle training will improve pulmonary functions in MS patients.

2. SUBJECTS AND METHODS

This study was conducted to investigate the effect of Inspiratory muscle training (IMT) on respiratory muscle functions in MS patients. This study was conducted on MS patients and evaluation of pulmonary function was conducted at outpatient's clinic in Sphinx University. While physical therapy intervention program done in both Deraya university and Sphinx University outpatient clinic Duration of study was between October 2024 till February 2025. The patient signed a consent form before enrollment in the study. The study was approved by Deraya University Center for Scientific Research ethical approval no DCSR-02025-44.

SUBJECT SELECTION:

Forty MS patients (26 women & 14 men) aged ranged from 25-45 years and body mass index BMI 25 to 29.9 kg/cm² were selected from neurology department of Minia and Assuit University Hospitals as a clinically definite MS according to

McDonald criteria. The diagnosis was confirmed by MRI and referred from a neurologist.

Ethical Consideration: -

- 1- The purpose of the study was explained for each patient.
- 2- Consent form was signed from each participant as an agreement to be included in the present study (appendix 1).
- 3- A bond of trust between patients and therapist developed to know everything about their disease course and to follow instructions carefully during the study.

The patients were randomly assigned into two groups equal in number:

Group (A): 20 patients (11 women & 9 men) of definite Multiple Sclerosis received IMT using IMT device for 15 minutes in addition to conventional chest physiotherapy in the form of deep breathing exercises mainly diaphragmatic breathing) for 15 minutes, 3 times/week for 8 weeks.

Group (B): 20 patients (14 women & 6 men) of definite Multiple Sclerosis received traditional breathing exercises only in the form of deep breathing exercises (mainly diaphragmatic breathing) for 15 minutes, 3 times/week for 8 weeks.

Inclusion Criteria: All patients had the following criteria

- 1- All patients were clinically diagnosed with definite MS, mild to moderate relapsing-remitting type.
- 2- One or more documented relapses were required in the two years prior to study entry. (The duration of the disease 2-10 years)
- 3- No patient in a period of MS relapse was included in the study.
- 4- Appropriate attention abilities.
- 5- Expanded disability status scale; EDSS ≤ 7 (Ambulant, Ambulant with assistance wheelchair patients)
- 6- Free from any other neurological problems.
- 7- Have different educational level.
- 8- Medically stable and under medical control.

Exclusion Criteria: -

The potential participants were excluded if they meet one of the following criteria:

- 1- Uncooperative patients and patients with depression rather than fatigue.
- 2- Deficits in attention or cognition, mini mental state examination.
- 3- Highly agitated individuals were also excluded if they were being unable to remain confined in the equipment
- 4- A previous history of chronic obstructive pulmonary disease or chronic bronchitis.
- 5- A previous history of smoking (Since 5 years ago.)
- 6- Tuberculosis and any abnormalities in chest X ray or cardiac diseases.
- 7- Patients complaining of acute respiratory illness at time of the study (Recent chest infection) or acute severe respiratory dysfunction.
- 8- Where relatively large pressure swings in the thorax or abdomen should be avoided (e.g. aneurism, uncontrolled hypertension)
- 9- All cases with bulbar dysfunction which is known to cause respiratory impairment.

Methods :(instrumentations & procedures)

INSTRUMENTATIONS: -

A. For evaluation: -

1. Weight and Height scale: Was used to measure the weight and height of each participant for assessment of predicted pulmonary function.
2. Pulmonary Function Test (Spirometry): A spirometer was used to measure FVC, FEV1, PEF, MVV and PImax during the spirometry test. Both groups used it before starting the study and again after 8 weeks at the end of the study. Figure (1).

Spirometry tests:

Preparation for pulmonary function tests:

Calibration of the instrument was done by a physician before performance of ventilatory function tests. The subject's data [name, age (years), sex, height (cm), weight (kg)] were entered to allow the spirometer to calculate the predicted values which appear on flow screen

Preparation for the subject:

Body weight and height measurements were obtained from all patients prospectively, as part of the pre-procedure package. It was handed to the patient with a clear demonstration of each of these commands. A review on what the different commands like "take a deep breath", "blow all the air out", "breathe naturally" and "hold your breath" signify before conducting the test is necessary to understand first. The test was made simple as per every patient and shown to them before applying the steps of the experiment.

All studies were performed in an upright position following the recommended standards¹⁶. A nose clip was placed on the individual to prevent any air from leakage through nostrils and then a new mouth piece was put in the person's mouth very securely and told to breathe a few times to get habituated to the instrument before test.

Repeated each test three times, the best result was selected for any parameter. A total of 3 maneuvers, and minimum¹⁷.

All ventilatory function test measurements were calculated as percentage of predicted normal values¹⁷. The spirometric readings (forced vital capacity (FVC), forced expiratory volume in one second (FEV₁)) were assessed. The third effort is best as evidenced by at least three attempts and measurements taken at each 3 min interval.

Predicted value of all measured parameters were converted to percentage.

From the FEV₁/FVC ratios (computed with FEV₁ and FVC).

Respiratory muscle endurance measurement.

The objective of ventilatory endurance testing was to establish the maximal sustainable ventilation (MSV), usually reported as a fraction of maximal voluntary ventilation (MVV)¹⁸. (MVV test— Deep and fast breaths for 10 to 15 seconds were done by yourself. When Do You Really Have the Maximum Voluntary Ventilation (MVV), The breath should be larger than tidal volume, but smaller than tidal capacity.

Measure respiratory muscle force:

Mouth: Maximal voluntary respiratory pressures. Maximal voluntary inspiratory [P_Imax], (or MIP) was a non-invasive estimate of inspiratory muscle force.

Position: Sitting position measurements were taken wherever possible to all patient's

Leak: to prevent pressure from muscles of cheeks and buccal muscles, a leak should be present with leak of equipment. A nose clip was used to prevent air from leaking out the nostrils of the patients.

Mouth piece: Flanged mouthpiece (as the ones mostly used for lung function testing)

Practice test: Mouthpiece practice test out to residual volume, and then exert a maximal inspiratory effort against a closed airway during the individual's inhale in the MIP measurement.



(Figure 1) Spirometer

B. Treatment procedure:

Group (A): Each patient was instructed to conduct Inspiratory Muscle Training (threshold inspiratory muscle training device) for 15 minutes as strengthening and train their inspiratory muscle in conjunction with standard chest physiotherapy

(around 15min/3times per week) Deep Breathing (mainly diaphragmatic breathing) 8weeks developed.

Threshold Inspiratory Muscle Training:

Threshold IMT Resistance (weighted) training of inspiratory muscles to threshold inspiratory muscle strength. Threshold trainer is a small handheld device supplied by Respironics. It has mouthpiece and a spring loaded calibrated valve It controls the inspiratory pressure training load which is always constant and the patient must generate inspiratory pressure so that inspiratory valve opens to permit air inhaled. The valve is calibrated and can be micromanaged to a fraction of percent of the maximum inspiratory pressure (PI max) per patient.

Patients received the following instructions for proper inspiratory training (IMT):

- Adjust red pressure indicator though control knob to the red edge. Something more, Also attach the mouthpiece and turn it to be used to this. A higher number equals greater effort
- Sit, position mouthpiece firmly and then inserts the nasal– clip on.
- Take the mouth piece in between the lips. Tighten nose clip and then start inhaling through the mouthpiece, until you feel fresh, valve is open come out air. In order to get air out of the device, the patient needs to exceed an inspiratory pressure greater than whatever their threshold pressure is set to, in order to compress spring and opening valve.
- Exhale through the mouthpiece and continue to inhale/exhale replacing it in mouth; without taking out device from mouth for 2 minutes.
- Take 1-minute rest.
- In the same manner until end of 15minutes.
- They were also provided with the use the IMT along with a modified Borg scale of perceived exertion and told to keep reminding themselves that which is VERY important to be considered should they be using it. Average (13 on We do never go above IV) If their breathlessness was anything worse than "mod", you must stop You: if non-exhaustive and patient has breathless only very little what they are up what that really was exercise, so reduce down train. only minute (less than 1 on the scale) they should increase their difficulty even more.
- Have the patient use this scale to record any changes and notify his provider.

Starting resistance:

Patients were initiated to breathe at the level of 30% maximal inspiratory pressure (MIP), baseline19.

Session duration: 15 mins20.

Frequency: One session each morning for the duration of 15 minutes per session

Group (B): Each patient was trained to perform deep breathing exercises mainly diaphragmatic breathing for 15 minutes, 3times/week for 8 weeks.

Diaphragmatic Breathing:

The patient was seated in a related position and a quick test of patients berating pattern was done by placing one hand on the sternum and other hand on the abdomen (at the umbilicus level) and

instruct the patient to take deep breath through nose and exhale through mouth. Then notice how much both hands rise. For optimal diaphragmatic breathing, hand on the abdomen must rise higher than hand on the chest.

Then as the patient breath in, through what the abdomen was pushed out and exhale through mouth, through breathing process the hand on the upper chest must remain as still as possible. Let the patient repeat breathing until achieve the ideal technique.

Inhale again through the nose and hold for five seconds. If five seconds is too long to hold, then hold as long as comfortable.

Exhale through the mouth for a count of six seconds, or one second longer than the inhale count.

Regular diaphragmatic breathing exercise will be performed by the patients three times a week for eight weeks; each patient will breathe in a rate of six breaths per minute and take rest

between exercises for one minute through a session of 15 minutes in order to sustain the benefits

Outcome measures:

All Participants underwent the Future Discovery spirometry pulmonary function test, which examined the respiratory cycle's FEV1, FVC, and FEV1/FVC, PImax, MVV and PEF.

3. DATA ANALYSIS

We used SPSS version 28 to conduct statistical analysis, and we set the significance level at $p < 0.05$. Both the mean and the standard deviation were part of the descriptive analysis. Pairwise t-tests were used for within-group differences in the inferential statistical analysis, whereas independent t-tests were used for between-group differences. Pearson correlation, t-test and one- way ANOVA were used to test the significant correlations and differences in patients' satisfaction scores with patient characteristics²¹.

4. RESULTS

4.1 Subject-related characteristics:

Table (1) represents the independent t-test of general characteristics of subjects between group A and group B. The statistical analysis revealed that there was no significant difference ($P > 0.05$) in values of mean general characteristics of subjects including age, height, weight and BMI between group A and group B.

Table (1): Mean values of general characteristics of subjects between group A and group B.

Items	Age (years)	Height (cm)	Weight (kg)	BMI (kg/cm ²)
Group A	35.90± 7.13	165.24± 4.78	71.98±4.89	26.14±1.39
Group B	35.84± 7.02	165.02± 4.96	71.35±5.28	26.47±1.31
t-value	0.301	0.349	0.236	0.563
p-value	0.735	0.691	0.778	0.566
Significance (p<0.05)	NS	NS	NS	NS

SD: standard deviation P: probability, NS: non-significance, S: significance

Results of patient in group A:

A.1. Results of FEV1, FVC, and FEV1/FVC.

As observed in table (2), Paired t-test between pre- and post-treatment revealed that there was significant difference ($P < 0.05$) in FEV1 and FVC FEV1/FVC with a percentage of improvement equal to 27.72%, 22.74%, but FEV1/FVC there was non-significant difference ($P > 0.05$) for group A.

Table (2) Mean values between pre and post FEV1, FVC and FEV1/FVC for men and women for group A.

Items	FEV1	FVC%	FEV1/FVC
Pre-treatment	66.09±14.48	68.99±14.05	94.79±4.45
Post-treatment	83.92±13. 70	84.82±12.12	95.96±4.99
Improvement%	↑ 27.72%	↑ 22.74%	↑ 2.52%
t-value	9.29	7.718	2.973
P-value	0.0001	0.001	0.605
Significance (p<0.05)	S	S	NS

FEV1: forced expiratory volume in first second, FVC: Forced vital capacity, FEV1/FVC: timed forced expiratory volume/ FVC: Forced vital capacity SD: standard deviation P: probability, NS: non-significance, S: significance

A.2. Results of PImax, MVV, and PEF.

As observed in table (3), The statistical analysis of the means of PImax, MVV, PEF by paired t-test between pre- and post-treatment revealed that there was significant difference ($P < 0.05$) in PImax, MVV, PEF with a percentage of improvement equal to 39.20%, 31.34%, 35% respectively in group A.

Table (3) Mean values between pre and post PImax, MVV, and PEF for men and women for group A.

Items	PImax	MVV	PEF
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Pre-treatment	51.59±11.01	61.29±5.78	57.37±7.66
Post-treatment	71.64±10.28	80.41±6.81	77.76±7.56
Improvement%	↑ 39. 20%	↑ 31.34%	↑35%
t-value	8.995	13.288	11.051
P-value	0.0001	0.001	0.001
Significance (p<0.05)	S	S	S

PI_{max}: maximum inspiratory pressure, MVV: maximum voluntary ventilation, PEF: peak expiratory volume, SD: standard deviation P: probability, NS: non-significance, S: significance

Results of patient in group B:

B.1. Results of FEV₁, FVC, and FEV₁/FVC.

As observed in table (4), Paired t-test between pre- and post-treatment revealed that there was no-significant difference ($P > 0.05$) in FEV₁, FVC and FEV₁/FVC 5.53%, 3.32%, 1.71% in group B.

Table (4) Mean values between pre and post FEV₁, FVC and FEV₁/FVC for men and women for group B.

Items	FEV ₁	FVC%	FEV ₁ /FVC
Pre-treatment	66.51±11.40	67.96±12.80	96.03±4.58
Post-treatment	70.05±11.69	70.11±12.77	97.78±3.95
Improvement%	↑ 5.53%	↑ 3.32%	↑1.71%
t-value	4.280	2.821	1.497
P-value	0.0001	0.001	0.605
Significance (p<0.05)	S	S	NS

FEV₁: forced expiratory volume in first second, FVC: Forced vital capacity, FEV₁/FVC: timed forced expiratory volume/ FVC: Forced vital capacity SD: standard deviation P: probability, NS: non-significance, S: significance

B.2. Results of PI_{max}, MVV, and PEF.

As observed in table (5), The statistical analysis of the means of PI_{max}, by paired t-test between pre- and post-treatment revealed that there was significant difference ($P < 0.05$) in PI_{max}, with a percentage of improvement equal 17.52%. But the statistical analysis of the means of MVV, PEF by paired t-test between pre- and post-treatment revealed that there was no-significant difference percentage of changes equal 7.73%, 8.95% respectively in men group.

Table (5) Mean values between pre and post PI_{max}, MVV, and PEF for men and women for group B.

Items	PI _{max}	MVV	PEF
Pre-treatment	52.78±12.95	58.42±10.17	64.56±7.87
Post-treatment	61.90±12.52	64.10±12.30	70.10±8.75
Improvement%	↑ 17.52%	↑ 7.73%	↑8.95%
t-value	8.407	3.675	7.497
P-value	0.00205	0.05655	0.0920
Significance (p<0.05)	S	NS	NS

PI_{max}: maximum inspiratory pressure, MVV: maximum voluntary ventilation, PEF: peak expiratory volume, SD: standard deviation P: probability, NS: non-significance, S: significance

Comparison between groups.

C.1. Comparison between group for FEV1, FVC, and FEV1/FVC.

Table (6) represent the independent t-test of FEV1, FVC, and FEV1/FVC mean values for men and women between group A and group B

The statistical analysis of the means pre- FEV1, FVC, and FEV1/FVC. Revealed that there was no significant difference ($P>0.05$) in pre study between group A and B, and there was significant difference ($P<0.05$) in post- FEV1 and FVC between group A and B in favor to group A. But there is no significant difference ($P>0.05$) post study for FEV1/FVC between group A and B.

Table (6) Comparative analysis of FEV1, FVC, and FEV1/FVC% mean values between group A and group B.

Items	FEV1(Pre)	FEV1 (Post)	FVC% (Pre)	FVC% (Post)	FEV1/FVC (Pre)	FEV1/FVC (Post)
Group A	63.12 ±15.02	81.52 ±12.17	68.99±14.05	84.82±12.12	94.79±5.42	95/96±4.74
Group B	66.51±11.40	70.05±11.69	67.96±12.80	70.11±12.81	96.03±4.58	97.78±3.95
t-value	1.4415	4.1425	1.5275	4.1315	1.5465	1.2725
P-value	0.1265	0.0031	0.3015	0.0351	0.1145	0.518
Significance (p<0.05)	NS	S	NS	S	NS	NS

SD: standard deviation P: probability, NS: non-significance, S: significance

C.2. Comparison between group for PImax, MVV, and PEF.

Table (7) represent the independent t-test of PImax, MVV, and PEF mean values for both groups A and group B

The statistical analysis of the means pre- PImax, MVV, and PEF. Revealed that there was no significant difference ($P>0.05$) in pre PImax, MVV, and PEF between group A and B, and there was significant difference ($P<0.05$) in post- PImax, MVV, and PEF between group A and B in favor to group A.

Table (7) Comparative analysis of PImax, MVV, and PEF mean values for group A and group B.

Items	Pimax (Pre)	Pimax (Post)	MVV (Pre)	MVV (Post)	PEF (Pre)	PEF (Post)
Group A	51.59±9.06	71.64 ±10.28	61.29±5.78	80.43±7.08	57.37±7.66	77.76±7.58
Group B	52.78±12.95	57.33±12.08	58.42±10.17	64.10±12.30	64.61±7.87	70.10±8.75
t-value	5.5910	5.2305	0.8005	3.6495	0.703	2.4055
P-value	0.830	0.021	0.476	0.01855	0.5145	0.1455
Significance (p<0.05)	NS	S	NS	S	NS	NS

SD: standard deviation P: probability, NS: non-significance, S: significance

5. DISCUSSION

Inspiratory muscle training (IMT) significantly improves (this) respiratory function in MS patients, as concluded from these results of the study. Particularly, those pulmonary function parameters PImax, FVC, FEV1, MVV and PEF showed significant increase in the IMT group (Group A) in comparison to control group (Group B). IMT is Important to the Strengthening of Respiratory Muscles and Improved Ventilation Efficiency in MS Patients (Klebeck & Nedjad, 2003)8. One of the key results from the study is a considerable improvement of PImax in Group A that coincides with previous studies reporting increased respiratory muscle strength after IMT interventions (Gosselink et al., 2000)4. The improvement in maximal inspiratory pressure suggests that IMT specifically affects and strengthens inspiratory muscles, decreasing the risk of respiratory issues observed frequently in MS, aspiration pneumonia (Chiara et al., 2006)3, ventilatory failure.

The Group A showed significant improvements in both FVC and FEV1, suggesting that IMT can improve lung capacity as well as airflow mechanics (Fry & Chiara, 2010)9. Previous research has found that respiratory muscle training is efficacious for respiratory function and cough potency in MS patients (Martín et al., 2014)22. The present data, a concomitant increase in MVV and PEF in IMT suggesting that both dynamic and static pulmonary functions of the ventilatory are enhanced via IMT (Mutluay et al., 2005)5 so as to provide adequate ventilation for MS patients.

Group B, which received conventional chest physiotherapy alone had a trend towards improvement in PImax and PDI participants however with much lower magnitude than Group A. This emphasizes the advantage of IMT over conventional chest physio and so emphasizes the need for MS Patients to integrate IMT into their pulmonary rehabilitation protocol (Kornek & Lassmann, 2003)2.

Clinical implications of the findings above are substantial. MS patients experience a significant amount morbidity and mortality due to respiratory complications that frequently result in hospitalization and decreased quality of life. IMT can be included to enhance the respiratory muscle strength and ventilation in order to mitigate the risk of respiratory-related complications by involving much the rehabilitation programs of clinicians. Moreover, the pulmonary function gains may further lead to improved exercise capacity and functional ability that are required for the maintenance of independence and quality of life in MS (Mutluay et al., 2007)6.

Importantly, although the outcomes of this study are encouraging the study has various limitations. Although the observed effects were statistically significant, sample size is relatively small and larger cohorts need to be tested in future studies to validate these results. Furthermore, long-term follow-up is required to determine the durability of IMT benefits over time. Further investigation is required to determine the right dose and duration of IMT for optimal therapeutic benefits in MS patients (Gosselink 2000, et al.)4.

Inspiratory muscle training (IMT)10-weeks study carried out on lower extremity mobility in ambulant individuals with multiple sclerosis (MS) [Results] Participants (EDSS 2.0–6.5) were allocated to an intervention group that received IMT or a control group. The intervention had a significant positive effect on inspiratory muscle strength ($P = .003$) and balance scores ($P = .008$), with a trend toward improvements in 6MWD ($P = .086$). IMT is of help in improving functional mobility in MS indicated the positive effect of respiratory function-driven improvements for balance and gait performance (Pfalzer 2011, et al.)23. Gender differences were found in relation to depression and stress; females reported higher levels of depression and stress compared to males. Similarly, females were experiencing more severe stress and anxiety symptoms (Shaheen et al., 2020b)23.

6. CONCLUSION

The primary choice in the rehabilitation program of multiple sclerosis patients should be Inspiratory Muscle Training (IMT), as it has been shown to significantly enhance pulmonary functions by increasing the strength of the respiratory muscle.

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Ethical approval

From Deraya University Center for Scientific Research ethical approval no DCSR-02025-44.

Consent for publication

Not applicable

Availability of data and materials

All data and materials are fully presented in the manuscript

Competing interests

The authors declare that they have no conflict of interest.

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