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Review Article

Functional Outcomes Associated with Inspiratory Muscle Strength Training in Chronic Obstructive Pulmonary Disease Subjects: Narrative Review

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Abstract

In this study, the literature review focuses on the available evidence for the effects of inspiratory muscle strength training (IMST) using a threshold loading device in participants with chronic obstructive pulmonary disease (COPD). The search involved a computerized database pertaining to studies that included the outcomes of a pressure threshold IMST published after the year 2000. Sixteen articles were selected which showed outcomes relating to inspiratory muscle strength (maximal inspiratory pressure), respiratory muscle function, dyspnea, functional capacity, and health-related quality of life in COPD participants. However, the IMST protocols varied in the different studies. Most of the studies demonstrated promising and significant improvements in most of the outcomes of IMST in COPD patients; however, the effects on respiratory function remain equivocal and need to be explored further through future research.

Keywords: Chronic obstructive pulmonary disease, dyspnea, exercise, inspiratory muscle strength training, inspiratory muscle training, maximal inspiratory pressure, quality of life, respiratory muscle training

Introduction

Weakness of inspiratory muscles in participants with chronic obstructive pulmonary disease (COPD) is of major clinical significance and importance. The maximum inspiratory pressure (MIP) that can be generated is a determinant of survival in severe COPD. In COPD, the diaphragm, which is the main inspiratory muscle, undergoes oxidative stress and sarcomeric injury which activates ubiquitin proteolysis causing contractile protein wasting. There is thus wasting and atrophy of the diaphragm muscle. Due to hyperinflation of the lung, there is flattening of the dome of the diaphragm and increase in the radius of its curvature. There is a shortening of the muscle fibers of the diaphragm due to a decrease in the length of its zone of apposition, putting the diaphragm at a mechanical disadvantage and reducing the force-generating capacity. There is also an alteration in the alignment of all the muscle fibers, all of which contribute to inspiratory muscle weakness.[1] Other mechanisms of compromise in COPD include malnutrition, use of corticosteroids which in the long run may lead to the myopathy of respiratory and peripheral muscles. Alteration in electrolyte and oxygenation status also alters muscle function. All these processes bring about a reduction in the capacity of the respiratory muscles in COPD, leading to a decrease in maximal pressure generation, denoted as lower values for MIP, maximal expiratory pressure (MEP), and exercise tolerance.[2] COPD is characterized by both pulmonary and extrapulmonary affection and manifestations. The expiratory airflow is limited (forced expiratory volume at the end of 1 s) is decreased due to the obstruction causing air trapping, hyperinflation, and this puts increased strain on respiratory muscles. Dyspnea is the main clinical feature experienced, and therefore, in order to avoid this feeling, patients with COPD tend to avoid any physical activity on exertion and tend to lead a more sedentary lifestyle, affecting exercise capacity, and in turn, health-related quality of life (HRQOL). There are various other contributing

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factors responsible for decreased exercise capacity such as ventilation-perfusion mismatch, hypoxemia, cardiovascular problems, and muscular changes or dysfunction.[3] Inspiratory muscle strength training (IMST) involves an exercise program which modifies various mechanisms involving physiology and other systems and brings about the strengthening of inspiratory muscles using different modes of devices such as resistive, pressure threshold, and normocapnic hyperpnea.

This narrative review provides a comprehensive outlook of the available literature pertaining to the research evidence for the effects of IMST in participants with COPD. The studies selected included pressure threshold inspiratory loading device having a numeric measure for the different loads as this would allow comparison across different sources of evidence in literature. The pressure threshold loading device was considered more reliable than the resistive inspiratory muscle training (IMT) device for this narrative review. The threshold loading device allows the amount of inspiratory load to be set and controlled. Thus, it can be used for achieving a therapeutic goal for the patient and assessing the progress.

Methods

The literature for this narrative review included studies that were published after the year 2000. The databases which were searched included PubMed, Cochrane, and Google Scholar using the phrases "Inspiratory muscle training in COPD, "Inspiratory muscle strength training in COPD," "Respiratory muscle strength training in COPD," and "Respiratory muscle training in COPD." All the articles were then reviewed to include studies which used a threshold loading device for IMST. A total of 16 articles were included which studied the effects of IMST on inspiratory muscle strength, respiratory muscle function, dyspnea, functional capacity, and health-related quality of life as the outcome measures.

Results

Inspiratory muscle training device and training protocols

Pressure threshold loading device

In this, the subject needs to produce a negative pressure to overcome the load set on the device to initiate inspiration. A spring-loaded poppet valve in the device provides a flow independent resistance to inspiration. The valve opens only when the pressure generated by the patient for inspiration exceeds that of the spring tension. Expiration is unoccluded and occurs through the expiratory flap valve.[4] The IMST protocol varies in terms of intensity and duration across the various reviewed studies. In a study, COPD participants were trained twice a day for 15 min each and six times a week for 2 months. The participants then started breathing at a resistance of 15% of MIP for a week and then increased incrementally to 5%–10% each session till they reached 60% of MIP.[5] In another study, thrice a week training was given for 6 weeks and each session lasted for 20 min. The participants started with an inspiratory load of 45% of pretraining MIP and then progressively increased till they achieved about 60% of their pretraining MIP.[4] In another protocol, training was for six times a week, comprising 30 min duration each for 2 months. Patients had to breathe at a resistance of 30% of their MIP for a week, and then load then increased incrementally to about 5%–10% till it reached 60% of their pretraining MIP values.[6] The investigators applied the protocol as five times/week for 5 weeks and each session for 30 min duration. The loaded breathing was of intermittent type for 3 min with a 2-min rest in between. Participants started breathing at a resistance of 40%–50% of their MIP which was progressively increased till 60% of the pretraining MIP was achieved.[7] In a different study, participants were trained daily for two sessions of 15 min duration each and five times a week for 3 weeks. Participants trained at 40% of their initial MIP load for each session, and the intensity was unchanged during the program.[8] Another study used a supervised training protocol for the patients which was thrice weekly for 8 weeks duration. Each session lasting for 2 min comprised seven cycles of 2 min of breathing on the threshold loading device followed by 1 min of rest. The load was kept at a maximum tolerable level for the participant for each 2 min work out interval and progressively increased over the training period.[9] In another protocol, IMT was given to COPD participants, 30 min daily, five times a week for 5 weeks, and resistance of 40%–50% of MIP was used.[10] In another study, training protocol was set at 30% of MIP for 8 weeks, seven times per week, once a day for 30 min duration. Participants had to maintain a breathing rate of 15–20 breaths/min.[11] The investigators employed a training protocol of 30% of MIP, consisting of 10, 2 min cycles for 8 weeks in COPD participants. The pressure load was gradually increased to 60% of MIP, and each session, lasting for a duration of 20–30 min.[12]

Effects of IMST on inspiratory muscle strength, respiratory muscle function, dyspnea, functional capacity, and HRQOL in COPD subjects

Structural adaptation and physiological outcomes were studied after IMT in participants with COPD in 2001. Fourteen male COPD participants were randomized and allocated into IMT and sham group. The IMT group was subjected to inspiratory loading of about 40%–50% of their MIP, and biopsies from external intercostal muscles and vastus lateralis were taken pre- and post-training period. There was a significant improvement in MIP from 77 ± 22 to 99 ± 22 cm H_2O in the IMT group as compared to the sham group. However, there was no difference in expiratory muscle strength pretraining and posttraining. The proportion of type 1 fibers increased by 38% and the size of type 2 fibers by 2% in the external intercostal muscles with no changes in the control muscle. Thus, inspiratory training brings about a specific functional improvement of the muscles of inspiration and adaptive changes in the structure of external intercostal muscles.[7] The effects of 1 year of specific targeted IMT in patients with COPD were studied in 2005. Forty-two participants with COPD were randomly divided into two groups: interventional and control. Interventional group received IMT for a year,

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and the control group received a low-load training program. The results showed that there was a statistically significant improvement in MIP from 71 ± 4.9 to 90 ± 5.1 cm H_2O at $P < 0.005$, 6MWD (from 256 ± 41 to 312 ± 54 m at $P < 0.005$), and HRQOL scores (St George Respiratory Questionnaire [SGRQ]) in the intervention group compared to the control group. In addition, there was a decrease in primary health care utilization and hospitalization days.[5] IMT as a part of the pulmonary rehabilitation (PR) program in COPD patients was studied in 2007. The study aimed at assessing the effect of adding IMT to the COPD patients already enrolled in PR. Thirty-four participants with a significant COPD completed a PR program for 12 weeks. Following the addition of IMT to a PR program, brought about a significant increase in MIP from 66 ± 4.7 to 78 ± 4.5 cm H_2O, improvement in 6-min walk distance (6MWD) from 254 ± 38 to 322 ± 42 m and significant decrease in dyspnea scores and improvement in the SGRQ score.[13] An original systematic review was updated in 2008 on IMT in adult COPD participants. The purpose was to determine the effect of IMT on inspiratory muscle strength, endurance, exercise capacity, dyspnea, and quality of life in adults with COPD. About 19 of the 274 articles in the original research matched the inclusion criteria. All of them compared targeted, threshold, or normocapnic hyperventilation IMT to sham IMT.

Sixteen meta-analyses were reported, demonstrating a significant increase in MIP by 11.6 cm H_2O and respiratory muscle endurance time by 4.4 min favoring the IMT group. There was also a significant improvement in the Borg scale measuring respiratory effort by 1.8 points and 6MWD of 32.1 m. The transient dyspnea index showed a significant improvement by 2.6 points and chronic respiratory disease questionnaire (CRDQ) total score by 0.3 points in the IMT group.[14] The state of evidence behind IMT in patients with COPD was studied in 2009. A systematic review was conducted using 15 articles, which were randomized trials of IMT versus sham IMT or no intervention in COPD participants. There were consistent improvements in MIP from −11 to −30 cm of H_2O, inspiratory muscle endurance, dyspnea, HRQOL, and walking test distance. However, there is no enough clarity that these increments were mediated through the improvement in inspiratory muscle strength and endurance.[15] The investigators carried out a randomized trial on IMT during PR in participants with COPD in 2015. In this trial, IMT versus no IMT was compared in 32 participants with COPD without inspiratory muscle weakness (MIP >60 cmH_2O) and receiving PR for 3 weeks. The outcomes assessed were dyspnea during Borg scale, 6MWD, and MIP. The results showed that IMT did not bring about an improvement in any of the outcome measures.[8] The effect of IMT on exercise capacity and quality of life in participants with COPD was studied in 2016. Sixty male participants with COPD were randomly assigned to three groups, namely Group A performed peripheral muscle exercise training along with IMT, Group B received peripheral muscle exercise training alone, and Group C had no training at all. The outcome measures in the study of MIP, MEP, 6MWD, dyspnea, BODE Index, and SGRQ-C showed a significant improvement in IMT group as compared to other groups after 4 and 8 weeks of training. Group A (study): pharmacological therapy along with peripheral muscle exercise training and IMT. Group B (control positive group): pharmacological therapy with peripheral muscle exercise training. Group C (control negative group): pharmacological therapy.[6] An interventional study was conducted by the investigators on the benefits of IMT (2015) in participants with COPD. The study population included 40 male participants with COPD in the age group of 45–65 years and divided randomly into the study and control group. However, there was no cutoff in MI*P* values to state inspiratory muscle weakness. A significant improvement in outcomes was seen such as in MIP, exercise capacity, and 6MWD after applying IMT.[3]

Effects of IMT on dynamic hyperinflation in COPD were studied in 2012. Inspiratory muscle strength and endurance training were performed daily for 8 weeks in ten patients of Stage 2 and 3 of Global Obstructive Lung Disease and MIP, endurance time during resistive breathing maneuvers (tlim) and inspiratory fraction (IF) were analyzed. Following IMT, there was a significant improvement in the inspiratory muscle performance of MIP from 7.75 ± 0.47 to 9.15 ± 0.73 cmH_2O and tlim from 348 ± 54 to 467 ± 58 s. IF is the ratio between inspiratory capacity and total lung capacity as measured through exercise testing, which also showed a significant increase and also a decrease in the perception of dyspnea.

A significant increase in IF indicates decreased dynamic hyperinflation and is a prognostic factor.[16] The authors analyzed the effect of high-intensity IMT on inspiratory muscle function, exercise capacity, dyspnea, and HRQOL in participants with moderate-to-severe COPD in 2006. It was a double-blind randomized control trial having two groups of COPD participants. One group received high-intensity IMT performed at highest tolerable inspiratory threshold load, increasing to 101% of baseline MIP, and other group underwent sham IMT at 10% of MIP for thrice a week for 8 weeks. The high-intensity training group showed an increase in the MIP by 29%, 6MWD by 27 m, improved dyspnea by 1.4 points, and fatigue (CRDQ) by 0.9 points per item.[9]

IMT in participants with COPD was studied in 2008, and it aimed at evaluating the impact of a specific IMT protocol on dyspnea, lung function, respiratory muscle pressure, exercise tolerance, and quality of life in COPD participants. It was observed that there was a significant increase in MIP and SGRQ in the protocol group when compared to the control group. However, there was no significant improvement in dyspnea, lung function, exercise tolerance, and MEP.[11] The effect of IMT on exercise capacity, dyspnea, and calf blood flow was studied in 2016.

The effects of controlled IMT were studied in COPD participants which was a meta-analysis in 2002. There was a significant improvement seen in maximal inspiratory pressure, exercise tolerance, and exercise dyspnea as measured by

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cardiopulmonary exercise test and increased calf blood flow as measured by plethysmography.[11] It was observed that both IMT in isolation and IMT as an adjunct to general exercise reconditioning significantly improved inspiratory muscle strength and endurance. There was an improvement in the functional exercise capacity (6MWD) also but was not significant statistically. However, a clinically significant decrease in dyspnea sensation at rest and during exercise was seen after IMT.[17]

Discussion

The most frequently reported functional outcome of IMST in COPD participants as observed from the selected studies was an increase in MIP which is an indicator of inspiratory muscle strength. Other significant changes were also documented post-IMT. Several studies reported a statistically and clinically significant improvement in the functional exercise capacity which was measured by 6MWD post-IMST. There was an increase in the walking distance within a time frame in participants with COPD. In addition, a decrease in the perception of dyspnea was also reported post-IMST. There was also a significant improvement in the HRQOL measured by CRQ or SGRQ or any other outcome measure post-IMST. The responses obtained in terms of the pulmonary function post-IMST were equivocal, hence not clear. There were no adverse events reported which were associated with the use of inspiratory muscle trainer (pressure threshold loading device) in the reviewed literature.

Conclusions

The IMST program has been successfully applied in participants with COPD to bring about an increase in inspiratory muscle strength, dyspnea, functional exercise capacity, and HRQOL.

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Conflicts of interest

There are no conflicts of interest.

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