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Comparing the Effect of Resistive Inspiratory Muscle Training and Incentive Spirometry on Respiratory Pattern of COPD patients

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Abstract

Background: Resistive Inspiratory Muscle Training (RIMT) is a well-known technique for rehabilitation of patients with Chronic Obstructive Pulmonary Disease (COPD). Incentive spirometry is another technique with potential viability for this application, but there is limited evidence in support of its efficacy in the rehabilitation of COPD patients.

Aim: The objective of this study was to compare the effect of resistive inspiratory muscle training and incentive spirometry on respiratory pattern of COPD patients.

Method: This study was a randomized clinical trial on 30 patients with moderate COPD who were referred, in 2011, to the pulmonary clinic of Emamreza Hospital of Mashhad (Iran). The patients were randomly divided into the RIMT and the IS treatment group. In both groups, exercise regimen consisted of two 15-minute sessions of exercise per day, in the morning and evening, four days a week for 4 weeks. Respiratory pattern (respiratory rate and depth) and dyspnea (at rest and during activity) were measured before and after exercise. Data was analyzed with the Mann-Whitney and ratio difference tests using SPSS v.11.5.

Results: The average age was 50.8±10.7 in the IS group and 51±10.8 in the RIMT group. The statistical tests found no significant difference between the groups in terms of post-intervention exertional dyspnea, dyspnea at rest, tidal volume, and respiratory rate ($P>0.05$); but post-intervention maximal inspiratory pressure and maximal voluntary ventilation in the two groups were found to be significantly different ($P <0.05$).

Implications for Practice: despite statistically superior performance of resistive training in improving the maximal voluntary ventilation and maximal inspiratory pressure, the difference between its results and the results of incentive spirometry is not clinically important, therefore positive clinical outcomes of incentive spirometry are sufficiently significant to encourage its use in COPD rehabilitation programs.

Keywords: Incentive spirometry, Respiratory Pattern, Chronic Obstructive Pulmonary Disease, Resistive Inspiratory Muscle Training

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Introduction

Chronic obstructive pulmonary diseases (COPD) are among the world's most important causes of mortality (1). These disease are the fourth leading cause of death in the United States and are expected to become the third leading cause of death in the world by 2020 (2). Every year, these diseases impose a significant cost to the national health care systems (1); in the United States for example, the cost imposed by these diseases is more than 32 billion dollars per year (3). It has been estimated that two-thirds of the treatment cost are associated with the COPD, and the more progressed is this disease the higher is the cost it imposes on the health care system (4). Statistics show that over the past 10 years there has been a steadily rise in the cost of medicine and hospital care required to control COPD (5). In addition, COPD has significantly adverse effects on employment status and occupational performance of people. In the past, COPD used to be considered as the illness of elderly, but it can also affect the people of working age. According to a research conducted by the US National Center for Health Statistics, 70% of COPD patients are less than 65 years old, and in 1994, OCPD was the cause a significant number of Americans leaving their job, and imposed a cost of about 9.9 billion dollars on the economy (6). COPD is also responsible for disability of about 2.2 million Americans (7). Patients with COPD constitute a large portion of admissions to the emergency room and hospital wards (8). In Iran, too, COPD is a major cause of admission to hospitals and occupation of hospital beds.

The high rate of mortality in COPD patients is associated with dysfunction of respiratory muscles, which triggers significant reduction in the pulmonary function indices (9). Weakness of respiratory muscle in these patients leads to clinical symptoms such as shortness of breath, which is due to imbalance between the ability and the workload of respiratory muscles. In effect, shortness of breath or dyspnea is the most common and disabling symptom in COPD patients (10).

The positive effects of rehabilitation programs and breathing exercises on COPD patients have long been proven (11). Several studies have shown that resistive inspiratory muscle training (IRMT) can be used effectively in such COPD rehabilitation programs (12-14). It has been reported that one advantage of this technique is its ability to improve both strength (Maximal Inspiratory Pressure; PImax) and endurance (Maximal Voluntary Ventilation, MVV) of respiratory muscles, which lead to alleviation of signature clinical symptoms such as dyspnea (15). Another technique with proven effect in improvement of respiratory function and lung expansion in postoperative patients is the incentive spirometry (16). The purpose of incentive spirometry is to encourage deep breathing and effective coughing, to achieve maximum dilation of the bronchi and prevent and treat pulmonary complications such as atelectasis (17). Incentive spirometry is frequently used and recommended for reducing the chance of complications and improving the pulmonary function in postoperative patients, but its efficacy in improvement of pulmonary function in COPD patients is still uncertain (16,18). Incentive spirometers are affordable and easy to use, have no side effect, and provide a direct feedback that act as an incentive for exercise (19). Despite such advantages, the use of incentive spirometers to improve the endurance of respiratory muscles and pulmonary function indices of COPD patients is not a typical practice, and there is little evidence supporting their efficacy for this application (18). In COPD patients, pathophysiology of the disease decreases the pulmonary function indices and this decline is reflected in clinical symptoms, so the use of simpler and more accessible training techniques capable of improving the pulmonary and respiratory function and clinical symptoms is of essential importance. Nurses play a key role in clinical care and education of COPD patient, so they can employ or recommend the simplest or the most effective methods of improving respiratory function based on latest scientific researches. The aim of this study was to compare the effects of resistive inspiratory muscle training and incentive spirometry on respiratory pattern of COPD patients.

Methods

This study was a randomized clinical trial on 30 COPD patients who were referred to lung clinic of Emamreza Hospital of Mashhad (Iran) in 2011. Assuming a confidence level of 95% (α= 0.05), test power of 90% (β = 0.1) and considering the closest study on the variable of respiratory muscle strength (12), sample size was selected to be 15 per group (x_1=52.5, s_1=18.5, x_2=78.8, s_2=21.4). Inclusion criteria were as follows: clinically stable patients with stage 2 COPD; Age of 40-65 years; FEV1 (maximum forced expiratory volume during the first second) of less than 80% and FEV1/FVC (ratio of FEV1 to forced vital capacity) of less than 70%; absence of heart problems and pulmonary

infections; residence in the city of Mashhad; passage of at least 3 months since smoking cessation. During the study, patients were taking their bronchodilator drugs and had a similar treatment regimen. Exclusion criteria were as follows: refusal to continue participating in the study; failure to adhere to treatment protocol during the four week period of the study; development of respiratory infection, fever, or cardiac involvement during the study; incidence of respiratory failure; dissimilarity of medication. The required data was collected using the form of demographic data enquiring about age, sex, weight, height, history and frequency of smoking, history and duration of illness, numeric rating scale (NRS) for rating dyspnea, spirometer Hi-801 (Chest CO., Japan) , Micro Respiratory Pressure Meter (Micro Medical Ltd., Chatham Maritime, UK), and OMAX wristwatch. Reliability of the spirometer (Hi-801) and the respiratory pressure meter was assessed through test-retest and their reliability coefficient was found to be respectively 0.98 and 0.88. The 0-10 numerical scale used to rate dyspnea is a standard instrument with approved reliability; nevertheless, its reliability was reassessed through test-retest and by examining the coefficient of correlation between the scores obtained at two separate weeks before the start of intervention, which resulted in reliability coefficient of 0.93. Reliability of the watch was confirmed through several comparisons with a digital clock. At each boot of spirometer and before measuring the pulmonary indices, proper calibration of this machine was checked by running an automatic test. Concerning the validity of the study instruments, it should be noted that spirometer and respiratory pressure meter are widely known as valid tools for measuring pulmonary indices.

To form the trial groups, first eligible participants were selected through convenience sampling, and were then randomly assigned to two groups of Resistive inspiratory muscle training and Incentive spirometry treatment. Overall, 37 patients entered the study, but 5 patients failed to complete the 4 week exercise program and 2 patients did not attend for the final evaluation and therefore excluded from the study; so ultimately, data pertaining to 30 patients were collected. Demographic and anthropometric information of patients in each group are presented in Table 1.

COPD was diagnosed by a pulmonologist based on criteria delineated by American Thoracic Society (ATS) (20). According to ATS, COPD patients are those that not only exhibit clinical symptoms but also have FEV1/FVC ratio of less than 70%. Confounding factors such as age, sex, height, weight, duration of illness, duration and frequency of smoking were controlled by random assignment of participants, and other factors such as respiratory infections and dissimilarity of medication regimen were controlled through inclusion and exclusion criteria.

Patients who entered the study were randomly assigned (by coin toss) to either the RIMT group (treated with resistive inspiratory muscle training) or the IS group (treated with incentive spirometry), in both of which treatment consisted of two 15-minute sessions of exercise per day, in the morning and evening, four days a week for 4 weeks.

Personal information was collected using demographic questionnaire and information on the disease was gathered through medical records and interviews with patients. Clinical stability and absence of respiratory infection was confirmed through examination by a specialist physician. To obtain a baseline for respiratory muscle strength, a spirometer was used to measure the maximal inspiratory pressure (PImax) and maximal voluntary ventilation (MVV) of all patients. Patients received the devised 4-week treatment with the help of a nurse and under the supervision of a pulmonologist. In the RIMT group, exercises were carried out using a resistive trainer machine with pressure threshold mechanism (Powerbreathe Gaiam Ltd., Southam, and Warwickshire, UK). Treatment consisted of two 15-minute exercise sessions per day, in the morning and evening, four days a week for 4 weeks. In the first week, the resistance level of the trainer was adjusted such that each patient exercised with 40 to 50 percent of his/her personal baseline maximal inspiratory pressure. In the second week, those patients who were able to take thirty breaths continuously and without exhaustion in the first week continued their exercises with the trainer adjusted to a higher resistant level.

In the IS group, exercises were carried out using a volumetric spirometer (Respiflo Tyco Healthcare Ltd, UK). In these sessions, the patient was seated in a comfortable chair, was asked to place his/her mouth on the mouthpiece of the spirometer, and then to inhale deeply and slowly until the spirometer gauge moves upward (the target volume was set to 3500 cc). Next, patient was asked to hold the breath for 3 seconds and then remove his/her mouth from the mouthpiece and exhale normally. This exercise was repeated 10 to 15 times per session, two sessions per day (in the morning and evening),

and four days a week for 4 weeks. Both groups of exercises were carried out in the clinic of Emamreza hospital in Mashhad.

Required data was collected through three measurements: the first measurement was performed before the intervention (to obtain baseline data), the second measurement was performed at the end of the second week, and the last measurement was carried out at the end of the fourth week. In these measurements, spirometric parameters involved with pulmonary indices (maximal inspiratory pressure and maximal voluntary ventilation) and clinical symptoms were recorded. Dyspnea was measured using Numerical Rating Scale (NRS) in two conditions of sitting (at rest) and walking. Respiratory rate and depth (indices of respiratory pattern) were measured and recorded in a clinical characteristics form devised by the researcher. To measure the respiratory rate, the patient was seated and the number of respirations (movement of chest) in one minute was counted. Respiratory depth and its changes after the treatment were measured and recorded using the spirometer Hi-801 (Chest co.) based on the expected tidal volume (10 cc per kg body mass).

This study was conducted by the approval of university ethics committee, which was gained by disclosing research method and objectives, and after obtaining written consent from all participating patients.

The collected data was analyzed with descriptive statistics and analytical tests using SPSS v.11.5. Normality of data was checked with Kolmogorov-Smirnov test, and data analysis was carried out with analysis of variance with repeated measures, Friedman test, and Mann-Whitney test. P values of less than 0.05 were considered significant.

Results

The participants were 23.2% female (seven women) and 76.7% male (23 men); 12 men and 3 women were in the RIMT group and 11 men and 4 women were in the IS group. The average age was 50.8± 10.7 in the IS group and 51±10.8 in the RIMT group. Statistical analysis showed no significant demographic difference between the two groups (P> 0.05). Both groups were homogeneous in terms of demographic variables such as age, weight, height, duration and frequency of smoking, and duration of illness (Table 1).

The Mann-Whitney test found no significant difference (P= 0.93) in terms of pre-treatment tidal volume between the RIMT group (605.3±84.8) and the IS group (604±133). In both RIMT and IS groups, the Friedman test showed significant intra-group difference (P<0.001) between baseline tidal volumes and measurements of week 2 and week 4. The results showed no significant difference (P= 0.45) between the post-treatment tidal volume of the RIMT group (690.6±94) and that of the IS group (717.6±140.9).

The Mann-Whitney test showed no significant difference (P=0.48) between the pre-treatment average respiratory rates of the RIMT group (21.7±1.5) and the IS group (21.3±1.7). The results of Friedman test showed significant intra-group difference (P<0.001) between baseline average respiratory rate and measurements of week 2 and week 4 in both RIMT and IS groups. The inter-group analysis however found no significant difference (P= 0.22) in terms of improvement of respiratory rate (from the baseline values) between the RIMT group (18.5±1.2) and the IS group (19.5±1.2).

The results of the Mann-Whitney test showed no significant pre-treatment difference between groups in terms of dyspnea at rest (P=0.72) or dyspnea during activity (P=0.15). The post-treatment measurements also showed no difference in terms of dyspnea at rest (P=0.47) between the RIMT group (0.6±0.5) and the IS group (0.47±0.5). The post-treatment measurements of dyspnea during activity, too, showed no significant difference (P=0.31) between in the RIMT group (1.1±3) and the IS group (1±0.0). The intra-group Friedman test showed that in both groups, only the improvement of dyspnea during activity was significant (P<0.001).

In addition, in both groups, analysis of variance with repeated measures showed a significant intra-group increase (P≤0.001) in respiratory muscle endurance (Maximal Voluntary Ventilation) and respiratory muscle strength (Maximal inspiratory pressure). The results of statistical analysis also showed significant difference (P=0.02) in terms of maximal voluntary ventilation between the RIMT group (49.3±2.5) and the IS group (43.1±5). This analysis also found a significant difference (P=0.02) in terms of Maximal inspiratory pressure between the RIMT group (-86.3±18.4) and the IS group (-80±16.2) (Table 2).

Table 1: Demographic and baseline anthropometric characteristics of the participating COPD patients

Variable	RIMT group Mean±SD	IS group Mean±SD	P
Age (years)	51±10.8	50.8±10.7	0.96 •
Weight (kg)	63.4±9.6	63.3±12.9	0.85 ••
Height (cm)	159±4.7	158±5.3	0.78 ••
History of smoking	13.5±3.7	15.2±7.6	0.44 •
Frequency of smoking (per day)	14.4±6.1	12.4±6.2	0.43 ••
Duration of illness	6.9±3.1	6.6±3.9	0.84 •
FEV1	1.5±0.2	1.5±0.3	0.78 •
FVC	2.3±0.3	2.3±0.4	0.80 •
FEV1/FVC	67.8±2	68.2±1.31	0.90 •
Tidal volume	605.3±84.8	604±133	0.93 ••
Respiratory rate	21.7±1.5	21.3±1.7	0.48 ••

• Independent t-test
•• Mann-Whitney test

Table 2: mean and standard deviation of pulmonary parameters affecting the respiratory pattern for the resistive inspiratory muscle training (RIMT) group and the incentive spirometry (IS) group before and after the intervention

Group Variable	Resistive inspiratory muscle training group Baseline	End of week 2	End of week 4	Intra-group P value	Incentive spirometry group Baseline	End of week 2	End of week 4	Intra-group P value	Inter-group P Value
Maximal inspiratory pressure (PImax)	-71.3±14.4	-78.9±14.8	-86.3±18.4	<0.001*	-74.8±15.9	-77.8±16.2	-80±16.2	<0.001*	0.02•••
Maximal Voluntary Ventilation (MVV)	34.9±0.7	42.9±3.4	49.3±2.5	<0.001*	35.2±2.5	38.4±4.3	43.1±5	<0.001*	0.02 •••
Tidal volume (TV)	605.3±84.8	658.7±87.3	690.6±94	<0.001**	604±133	660.3±138	717.4±140.9	<0.001**	0.45•••
Respiratory rate (RR)	21.7±1.5	20±2	18.5±1.2	<0.001**	21.3±1.7	20±1.2	19.5±12	<0.001**	0.22•••
dyspnea (exertional)	2.1±0.7	1.1±0.3	1.1±0.3	<0.001**	1.8±0.4	1+0.0	1±0.0	<0.001**	0.31••••
dyspnea (at rest)	0.6±0.5	0.6±0.5	0.6±0.5	1**	0.53±0.52	0.53±0.52	0.47±0.52	0.36**	0.47••••

• Analysis of variance with repeated measures (intra-group comparison)
••Friedman test (intra-group comparison)
••• Ratio difference test
•••• Mann-Whitney test

Discussion

This study examined the effect of incentive spirometry on the respiratory pattern and dyspnea of COPD patients, in comparison to the effects of resistive inspiratory muscle training. The results showed that in patients with moderate COPD, supervised short-term incentive spirometry can increase respiratory function, alleviate dyspnea and improve respiratory pattern, and can therefore be incorporated as a supplemental therapy into the routine COPD rehabilitation programs.

Pulmonary complications is one of the leading causes of death in patient who undergo thoracic surgery as well as many other patients, and incentive spirometry is the most viable tool for preventing these complications. The findings of previous studies on the efficacy of spirometry in COPD rehabilitation programs are very divergent, and its efficacy in non-surgical patients is yet to be properly investigated. The results of a systematic review by Overend et al. (2001) titled "the effect of incentive spirometry on postoperative pulmonary complications" reported that there was no evidence supporting the positive effect of incentive spirometry on reduction of postoperative pulmonary

complications and improvement of postoperative pulmonary indices (21). In contrast, a meta-analysis by Thomas et al (1994) report that incentive spirometry, deep breathing and intermittent positive pressure breathing reduce postoperative pulmonary complications and improve pulmonary indices (22). Those results of the present study that are in regard to pulmonary indices of maximal inspiratory pressure and maximal voluntary ventilation after spirometry are consistent with the results of Thomas et al.

Incentive spirometers are designed to emulate a sigh or a natural yawn and can be used in breathing exercises by encouraging the patient to take deep and long breaths. The use of spirometer improves the internal pressure of the lung, respiratory volume, and respiratory muscle function (23). In a study by Scherer et al. (2000) titled "respiratory muscle endurance training in chronic obstructive pulmonary disease", these researchers examined the effect of 8 weeks of resistive training on COPD patients in comparison to a control group performing respiratory exercises with incentive spirometer, and reported that respiratory exercises with incentive spirometer increase the maximal inspiratory pressure and improve dyspnea and respiratory muscle function (24). In a study titled "the effects of incentive spirometry on pulmonary functions", Igarashi et al. (1994) examined the effects of incentive spirometry on pulmonary function of elderly and COPD patients, and reported that both the control group and the group of COPD patients showed a significant improvement in the parameters of pulmonary function (25). In contrast, study of Basoglu et al. (2005) found no improvement in pulmonary indices as the results of incentive spirometry. Pande et al. (2005) also reported that incentive spirometry showed no effect on respiratory rehabilitation of COPD patients (26). Our results support the results of Scherer and Igarashi and indicate that incentive spirometry can improve the pulmonary indices including the maximal inspiratory pressure. The aim of respiratory rehabilitation programs is to improve not only the pulmonary indices but also the clinical symptoms. It has been shown that rehabilitation programs inspiratory muscle training can improve strength and endurance of respiratory muscles and alleviate the shortness of breath (27). In this study, both groups (incentive spirometry and resistive inspiratory muscle training) exhibited significant improvement in dyspnea, and results showed no significant difference between the two groups in terms of dyspnea at rest or during activity. The study of Tiwary et al. (1989) titled "the effect of incentive breathing on lung functions in COPD patients" reported that incentive spirometry significantly improved the dyspnea of COPD patients (28).

In the present study, resistive training and incentive spirometry interventions both improved the respiratory rate and tidal volume of COPD patients. Although, there was no significant inter-group difference between the post-treatment measurements of tidal volumes, the intra-group improvement of tidal volume in the incentive spirometry group was better than that in the resistive training group. In a study by Fregonezi et al. (2005), it was reported that resistive training with diaphragmatic and pursed-lip breathing clearly improved the respiratory pattern of patients with myasthenia gravis, and this effect was reflected in improved respiratory rate and tidal volume of patients (29). The present study also supports the results of previous studies reporting the positive effects of resistive training on respiratory muscle endurance (27, 30, and 31). Our results also showed a significant increase in the respiratory muscle endurance (represented by MVV) in the resistive inspiratory muscle training group.

In this study, the effect of interaction of age, sex, duration of smoking, and duration of illness with training techniques on the changes of respiratory muscle strength and endurance was found to be insignificant. Despite statistically better performance of resistive training in improving the maximal voluntary ventilation and maximal inspiratory pressure, difference between the two groups is not clinically significant, and both methods show efficacy in improving these indices.

Our results regarding the improvement of maximal voluntary ventilation and maximal inspiratory pressure through incentive spirometry show that despite the superiority of resistive training in improving these two indices, the use of supervised incentive spirometry can be as effective in respiratory exercises of COPD patients as it is in preventing postoperative pulmonary complications. It is also necessary to remember that incentive spirometers provide a direct feedback that serves as a stimulus for exercise. These results also support the findings of the study conducted by Mokhtar et al. (2003) on heart patients undergoing valve replacement surgery, which reported that supervised incentive spirometry not only prevents postoperative complications, but also triggers statistically significant improvements in pulmonary function (32).

The limitations of this study are as follows: this study was conducted on patients with stage 2 COPD who had clinical cardiovascular stability, so its results may not be generalized to patients with more advanced stages of COPD. Also, because of time limitations, the long term effects of intervention was not examined, so the question that which technique has a better effect on sustainable improvement of respiratory function, periods of exacerbation, and the need for short-acting inhaled bronchodilators in COPD patients is yet to be answered.

Implications for Practice

The findings of this study show that despite statistically better performance of resistive training in improving the maximal voluntary ventilation and maximal inspiratory pressure, the difference between its results and the results of incentive spirometry is not clinically significant, so the positive clinical outcomes of incentive spirometry are sufficiently significant to encourage its use in COPD rehabilitation programs. The authors suggest further studies on the effects of these techniques on respiratory condition of patients with advanced chronic pulmonary diseases, and induction of more sustainable effects through exercises. Long-term studies to compare the sustainability of the effects induced by these two techniques are also highly recommended.

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Conflict of interest

The authors declare that there is no conflict of interest.

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