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Walking distance improvements in chronic obstructive pulmonary disease patients after home-based daily respiratory muscle training: A pilot study

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Abstract

This study investigated the effects of home-based daily inspiratory muscle training (IMT) on inspiratory muscle strength and exercise capacity among chronic obstructive pulmonary disease (COPD) patients. The participants comprised 14 elderly men with moderate to severe COPD, who were randomly divided into two groups, the IMT group (n = 7) and the control group (n = 7). In the IMT group, participants followed a daily home-based IMT exercise program at moderate resisted load for 6 weeks, while the control group had no intervention. Maximal inspiratory pressure (MIP, an index of inspiratory muscle strength), 6-minute walk distance (6MWD) and cardiovascular responses following the 6-minute walk test (6MWT) were examined at baseline and after the program. The results showed that, after the training period, the inspiratory muscle strength and 6MWD values in the IMT group were significant increased compared with control group (p = 0.010 and 0.038 respectively). Greater improvement in cardiorespiratory responses following 6MWT was observed in the IMT group, as exhibit by a significant decrease in dyspnea and heart rate compared with the control group. Additionally, inspiratory muscle strength was significantly positively associated with 6MWD (r = 0.735, p = 0.003). In conclusion, a 6-week home-based IMT exercise program is an effective intervention for increased respiratory muscle strength, increased exercise capacity, and attenuated dyspnea among COPD patients. Such, a program might be a feasible alternative for COPD patients, especially those who are unable to adhere to the aerobic exercise recommendations, to enhance their exercise.

Keywords: Breathing exercise, Home-based exercise, Inspiratory muscle training, Six-minute walk test

1. Introduction

Worldwide, more than 250 million people live with chronic obstructive pulmonary disease (COPD). In line with this, in 2000, Thailand reported an estimated 1,502,000 cases of COPD [1,2], moreover, the number of cases has exhibited an upward trend over time. In fact, COPD is the sixth leading cause of death in Thailand [3]. COPD commonly involves airflow limitation and hyperinflation, resulting in respiratory muscle weakness that contributes to dyspnoea, decreased exercise capacity and decreased quality of life [4,5]. Previous research has found that respiratory weakness limits exercise tolerance, elderly COPD patients with inspiratory muscle weakness have been found to exhibit a 48% decrease in their six-minute walk distance (6MWD) when compared with healthy age-matched patients [6]. Furthermore, previous studies have reported that moderate to severe symptoms on the dyspnea scale are correlated with low 6MWD results [7]. Therefore, it is evident that respiratory muscle weakness is associated with dyspnea and poor exercise tolerance.

Aerobic exercise is considered important for enhancing exercise capacity among COPD patients. A meta-analysis showed that aerobic training of low to moderate intensity improves exercise tolerance in COPD patients, as indicated by increases in 6MWD and endurance shuttle walk test results [8]. Moreover, Audrey et al. observed significant increases in peak oxygen consumption in participants with COPD after 6 weeks of treadmill training. As mentioned above, there is strong evidence supporting the efficacy of aerobic training on improved exercise capacity [9]. However, despite the health benefits of regular aerobic exercise, prior studies have reported a low attendance rate for such sessions among participants with COPD, especially those involving long training durations [10]. Since a lack of time is cited as one of the major barriers to participation in training, exercise that is effective and has a low time cost is of interest from an adherence perspective [11]. Interventions that involve shorter durations and do not aggravate symptoms might be an alternative treatment for this patient group.

Inspiratory muscle training (IMT) is a breathing exercise conducted using inspiratory resisted loads [12]. Many previous studies have reported the benefits of IMT in COPD patients, including increased inspiratory muscle strength, relief from dyspnea, decreased hyperinflation and increased quality of life [6,13,14]. However, the effect of IMT on the functional capacity of patients remains a controversial issue. Beaumont et al. and Figueiredo et al. reported improvements in 6MWD of approximately 43.00 and 34.28 m, respectively, after COPD patients completed an IMT program [14,15]. However, other evidence has shown no significant change in 6MWD [16].

Home-based IMT training is an alternative intervention that could promote exercise adherence because of its qualities of cost-effectiveness, flexibility in terms of the timing of exercise sessions, and accessibility for patients [4,17]. Therefore, the present study was designed to examine this issue and validate the benefits of IMT. The study investigates whether 6 weeks of regular home-base IMT could improve respiratory muscle strength and functional capacity in patients with COPD. The purpose of the study is to investigate the effect of IMT on inspiratory muscle strength and exercise capacity, as well as to determine the association between respiratory muscle strength and exercise capacity.

2. Materials and methods

2.1 Participants

Fourteen male COPD patients (aged 40–70 years) were recruited from a district hospital in Khon Kaen province. They were diagnosed as COPD patients with GOLD stage II–III, in accordance with the Global Initiative for Chronic Obstructive Lung Disease guidelines [5]. All patients were in stable condition, with no respiratory exacerbations for at least 8 weeks before the study; they had not been involved in any exercise or rehabilitation program. Participants were excluded from the study if they had other complications that limited exercise performance and mobility.

2.2 Study design

The participants were randomly assigned to either the control or the IMT group. They were familiarized with the experimental procedures and IMT exercises under the supervision of a physical therapist 1 week prior to the study [18]. All participants were advised to refrain from consuming alcohol, caffeinated beverages, or vigorous exercise for 24 hours and heavy meals for at least 4 hours before measurement. The outcome measures, including maximal inspiratory pressure (MIP), 6MWD, and training response after the 6-minute walk test (6MWT), were assessed in a pre-training program. Participants in the IMT group received an IMT exercise program for 6 weeks, while the control group participant was instructed to continue their usual physical activity. The control group was given lifestyle modification advice based on the Thoracic Society of Thailand (TST) recommendations regarding patient education, smoking cessation and dyspnoea/symptom management.

At the end of the 6-week program, all variables were measured; this was done on the day following the last exercise session. The testing and retesting sessions were scheduled at a similar time of day to minimise the potential effects of diurnal variation.

2.3 Inspiratory muscle training protocol

The IMT group was instructed to perform the home-based IMT exercises using Threshold Inspiratory Muscle Trainer equipment (Koninklijke Philips N.V., Netherlands). The IMT protocol was designed based on a respiratory muscle training program, as previously described [4,17,19]. Exercise intensity was set at 60% of the MIP resisted load; participants were instructed to complete five sets of IMT daily, with six breaths/set and 1 minute of rest after each set, for a period of 6 weeks. To maintain the training intensity, every 2 weeks during the study period, MIP was measured to an adjusted load of 60% of the actual MIP in each participant. During the familiarisation period, participants were instructed to perform IMT under the supervision of a physical therapist to ensure that they were able to follow the program properly. Participants were encouraged to breathe with their diaphragm and inhale with maximum effort while retaining as spontaneous a breathing rate during IMT breathing as possible. In addition, they received an instruction manual for the prescribed exercise. During the home-based exercise program, the participants were contacted weekly by phone to remind them to follow the exercise program. Moreover, a home visit from a researcher was conducted every 2 weeks to recheck their exercise session and ensure the exercise training programme was follows.

2.4 Outcomes

The MIP for each individual was measured using a MicroRPM Respiratory Pressure Meter (PhysioParts, UK). Participants performed three trials of maximum inspiratory manoeuvres with a 1-minute interval for rest between tests. The most significant of the three trials was used as the resisted load, with values varying by no more than 5% from the highest value [20].

The 6MWD was conducted based on AST guidelines [21]. The participants were instructed to walk at their own speed under the supervision of a physical therapist for a span of 30 m indoors along a flat, straight corridor. The distance after the 6-minute walk was recorded for analysis. Training response from the 6MWT included estimations of blood pressure (BP), heart rate (HR), blood oxygen saturation (SpO_2), and rating of perceived exertion (RPE). The BP, HR, and SpO_2 were measured using a vital sign monitor (Nihon Kohden Vismo, Japan). The measurement procedure followed the standard guidelines of the American Heart Association [22]. In addition, RPE was assessed using the modified Borg scale [23] that ranks the magnitude of difficulty in breathing from 0 (non) to 10 (maximal).

All measurements were made by one assessor. Prior to the study, observations of intra-observer repeatability were obtained, showing an intra-class correlation coefficient of > 0.90 for all parameters.

2.5 Statistical analysis

Statistical analysis was performed using the Statistical Package for Social Sciences (SPSS) version 26, and the normality of distribution was tested by conducting a Shapiro–Wilk test. Continuous data were presented as mean ± standard deviation. The paired t-test and student t-test were used to make within-group and between-group comparisons, respectively. To compare the exercise and control groups, we carried out the Chi-square test for categorical variables. In addition, Pearson's correlation coefficient and multiple regression analysis were deployed to explore the association between variables, wherein the statistical significance was set at an alpha level of < 0.05.

3. Results

3.1 Participant characteristics

A total of 14 male COPD patients, with an average age of 67.07 ± 4.23 years, participated in this study. Other baseline characteristics of the participants are summarized in Table 1**.** No statistical differences were observed between the control and IMT group in terms of their baseline characteristics ($p > 0.05$). Importantly, none of the participants in the IMT group reported any adverse effects during the study period.

3.2 MIP

After completion of the 6-week IMT training, observations of MIP in the IMT group showed a significant increase of around 39.14 cmH_2O (68.93 %) compared to its initial value ($p = 0.005$). In addition, the post-program MIP of the IMT group was significantly higher than that of the control group ($p < 0.001$), at approximately 48.71 cmH_2O (95.25%) (Figure 1).

3.3 6MWD

At baseline, there were no statistical differences in 6MWD between the IMT and control groups ($p = 0.227$). A significant increase in 6MWD (+ 50.14 m) was observed after 6-week IMT training program ($p = 0.019$) (Figure 2).

Table 1 Participant characteristics and baseline MIP and 6MWD

	Control group (n = 7)			IMT Group (n = 7)			*p*-value
Age (years)	66.43	±	4.54	67.71	±	4.15	0.591[a]
Weight (kg)	52.69	±	9.79	53.31	±	5.64	0.885[a]
Height (cm)	161.00	±	6.38	160.43	±	6.88	0.653[a]
BMI (kg/m^2)	20.32	±	1.69	20.70	±	1.61	0.794[a]
MIP (cmH_2O)	48.86	±	16.55	60.71	±	9.36	0.125[a]
6MWD (m)	339.29	±	28.84	321.57	±	22.92	0.227[a]
COPD severity							
Gold stage II (n)		3			4		0.659[b]
Gold stage III (n)		4			3		0.270[b]
Comorbidity hypertension (n)		3			5		0.212[b]

Data present as mean ± SD
[a] Student t test
[b] Chi square test

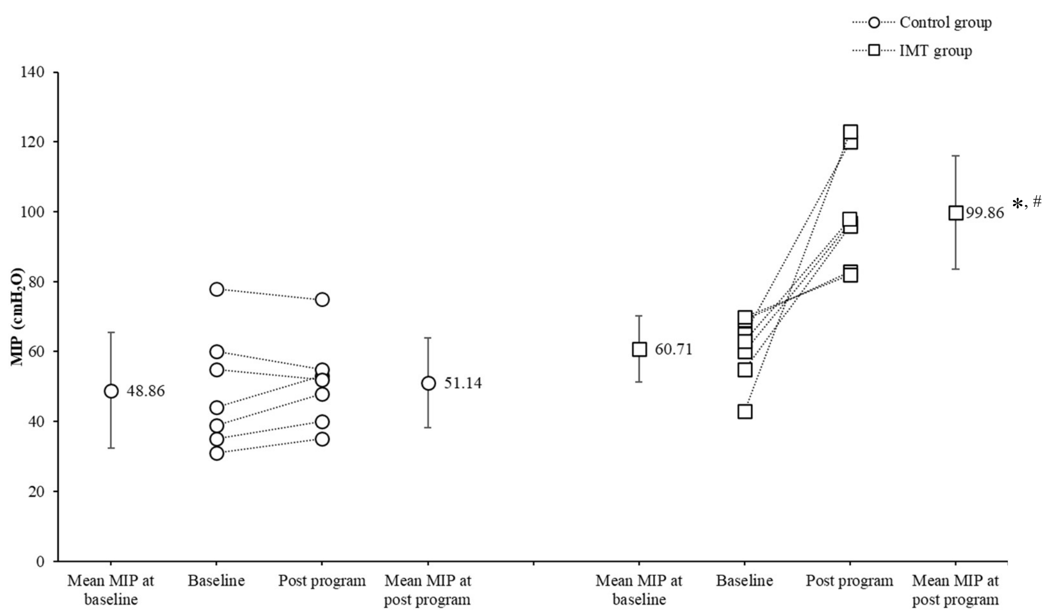

Figure 1 MIP in control group and IMT group at baseline and post program.
* significant difference within group when compared with baseline ($p < 0.05$)
[#] significant difference between group ($p < 0.05$)

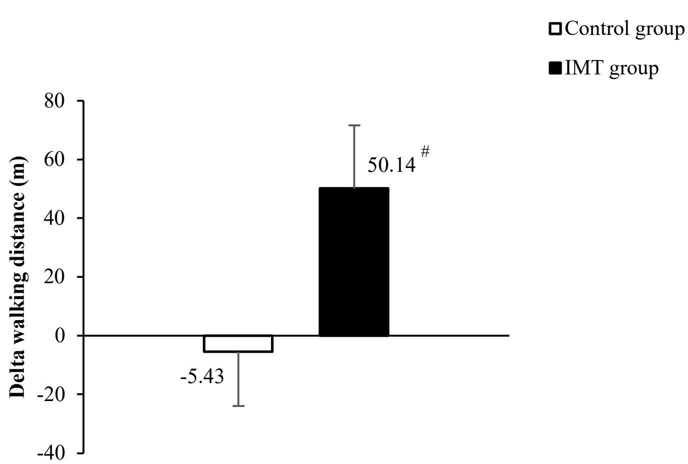

Figure 2 Changes in 6MWD in control group and IMT group.
[#] significant difference between group ($p < 0.05$)

3.4 Cardiovascular response after performing the 6MWT

The cardiovascular response following the 6MWT is presented in Table 2. A significant decrease in dyspnea scores was observed after the IMT exercise ($p = 0.007$). Moreover, at the end of the exercise program, the RPE score was significantly lower in the IMT group than in the control group (1.85 score, $p = 0.003$). HR following the 6MWT was significantly lower, compared to the control group after the program ($p = 0.036$). Nevertheless, there were no statistically significant changes observed in systolic blood pressure (SBP), Diastolic blood pressure (DBP), or SpO_2 after the 6MWT in either of the two groups.

3.5 Correlation between MIP, 6MWD, and outcome measures

After the intervention, the MIP for the whole cohort was correlated with the 6MWD (r = 0.735; Table 3). The MIP was also inversely associated with the RPE (r = -0.606) and HR (r = -0.562) at the end of the 6MWT (Table 3). Using multiple regression analysis to quantify the relationship between all the parameters, it was found that 6MWD was independently related to MIP ($p = 0.003$). Changes in these two parameters explained 54% of the variance.

Table 2 Cardiovascular response after performed 6MWT in control and IMT at baseline and post program.

Variables	Group	Baseline			Post program		
RPE (score)	Control	4.71	±	0.76	4.71	±	0.49
	IMT	4.71	±	0.49	2.86	±	1.21$^{*,\#}$
HR (bpm)	Control	95.71	±	11.73	95.86	±	10.12
	IMT	91.57	±	9.98	83.00	±	10.31$^{*,\#}$
SBP (mmHg)	Control	148.86	±	11.07	152.57	±	13.19
	IMT	144.86	±	7.29	138.86	±	10.21
DBP (mmHg)	Control	77.29	±	8.62	78.57	±	7.18
	IMT	74.88	±	6.12	74.57	±	7.28
SpO2 (%)	Control	96.71	±	2.06	97.14	±	1.77
	IMT	95.86	±	3.39	97.57	±	1.90

Data present as mean ± SD
* significant difference within group when compare with baseline ($p < 0.05$)
$^{\#}$ significant difference between group ($p < 0.05$)

Table 3 Correlation between MIP, 6 minute-walk test distance and outcome measure at post program.

Variables	r	*p*-value
MIP (cmH_2O)		
6-minute walk distance (m)	0.735	0.003
RPE at end of 6-minute walk test (score)	-0.606	0.022
Heart rate at end of 6-minute walk test (bpm)	-0.562	0.036

4. Discussion

As a main finding, our study indicates that a 6-week home-based daily IMT programme improved respiratory muscle strength and functional performance among patients with COPD, as evidenced by significant increases in patients' MIP and 6MWD values. In addition, we identified that, after the 6MWT, dyspnoea and HR were both attenuated in the IMT group following the program.

IMT training has received much clinical attention in terms of its value for COPD patients [24]. Chung et al. suggested that inspiratory muscle strength improves in response to 8 weeks of threshold IMT in patients with stage II–IV COPD [6]. In addition, significant improvements in dyspnea, exercise capacity and quality of life have been demonstrated [6]. Likewise, a study by Charususin et al. observed improvements in maximum inspiratory mouth pressure (PI_{max}) when determining exercise intensity among COPD patients after the IMT program [25]. These findings suggest that improvements in respiratory muscle strength after IMT training could be proportional to improvements in physical capacity. The results of our study indicate that MIP increased to around 39 cmH_2O after the program. Furthermore, a clinically meaningful improvement in respiratory muscle strength was identified [26].

Apart from respiratory muscle strength, the current study demonstrated the effectiveness of IMT on exercise capacity, as evidenced by a significant increase in 6MWD (50 m). Consistent with our findings, previous meta-analysis studies have revealed that IMT exercise in COPD participants increases their 6MWD to approximately 32 m [26]. Moreover, in the present study, inspiratory muscle strength was associated with 6MWD after the intervention. In a contrasting finding, previous research has concluded that, although IMT enhances inspiratory muscle strength, it fails to improve aerobic capacity among patients with moderate to very severe COPD[16]. Thus, increasing the training period was recommended to improve the clinical significance of 6MWD in patients with COPD [27].

The possible mechanisms for respiratory muscle strength improvement as a result of IMT training may be attributed to changes in muscle property and function. First, IMT exercise increases inspiratory muscle strength by increasing the size of type II muscle fibers [16] as well as diaphragmatic thickness [28]. Second, higher inspiratory muscle strength is associated with shorter inspiratory time, leading to decreased hyperinflation [13]. The resting length of the diaphragm muscle returns to its appropriate length after IMT, thus providing more forceful contraction [6,13]. In the present study, a moderate correlation was found between MIP and 6MWD in patients with COPD, indicating that greater inspiratory muscle strength was partly related to better functional capacity. It might be concluded that the IMT program enhances blood flow and oxygenation to the exercising limb due to a decrease in peripheral vascular resistance, leading to greater exercise capacity [29]. Taken together, these potential physiological mechanisms may support the efficacy of IMT in enhancing inspiratory muscle strength as well as improving the functional exercise capacity of COPD patients.

As observed in this study, after the 6MWT, both HR and RPE exhibited significant decreases following IMT training, indicating that IMT increases exercise tolerance. This conclusion is supported by Langer et al., who studied the effect of IMT on dyspnea during exercise in COPD patients. These researchers' results showed that the Borg scale decreased significantly after 8 weeks of training. In addition, reductions in dyspnea ratings were significantly correlated with improvements in respiratory muscle strength (PI_{max}) following IMT [30]. Similarly, Beaumont et al. identified a significant decrease (-1.4 score) in the Borg scale at the end of the 6MWT after 4 weeks of IMT combined with pulmonary rehabilitation [24]. The results of this study are consistent with those of Laoutatis et al., who reported a significant inverse association between the percentage decrease in dyspnea and the increase in cardiovascular endurance following IMT exercise. This suggests that a reduction in dyspnea may be related to improvements in inspiratory muscle performance, resulting in enhanced exercise efficacy [31]. Consistent with this, our analyses also found a significant inverse correlation between MIP and the RPE score at the end of the 6MWT ($r = -0.61$). The attenuation of dyspnea after IMT can probably be attributed to increased inspiratory muscle capacity [32]. In addition, we documented an alleviation in HR responses following the 6MWT in the IMT group, which is an important predictor of the mortality rate in individuals with COPD. Data from systematic reviews also confirm the beneficial effect of IMT on autonomic control, as indicated by the reduction in sympathetic outflow and increase in vagal modulation after completing an IMT programme [33]. Therefore, the enhancement of inspiratory muscle function after IMT may increase fatigue resistance and improve autonomic modulation by alleviating sympathetic activity.

Some limitations were observed in this study. First, the inclusion of a small sample and the absence of female participants could make it difficult to generalise the results. Second, the training program was carried out only for a short period; therefore, further research is required to investigate the effect of IMT over an extended period. Finally, this study was not designed to elucidate the mechanism of IMT in the respiratory metaboreflex. Future studies will be required to reveal this mechanism

5. Conclusion

IMT, as a form of exercise training, improves walking capacity and is beneficial when it comes to alleviating COPD symptoms. This study showed that, for COPD patients, IMT training is a simple home-based therapy and poses significant improvements to respiratory muscle strength and functional capacity. Moreover, it was found that IMT reduced RPE and HR in response to exercise among COPD participants. Thus, home-based IMT exercise could be an alternative exercise mode for patients with moderate to severe airway obstruction. Overall, the data collected in this study indicated that IMT could be used as self-exercise for COPD patients, especially patients who are unable to meet aerobic exercise recommendations, to enhance their exercise capacity.

6. Ethical approval

The methodology of this study was reviewed and approved by The Ethical Committee of Research in Human, Khon Kaen University (HE622217).

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